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Final Report

Aeronautical Meteorology System
Technical Assistance Project
Executive Summary

Prepared for

Unidad Administrativa Especial de Aeronáutica Civil
Aeropuerto El Dorado
Bogotá, Colombia

by

Earth Satellite Corporation

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EXECUTIVE SUMMARY

1.0 Introduction

The evaluation to modernize the Colombia Aviation Meteorological System was funded by a technical assistance grant awarded by the United States Trade and Development Agency (TDA) at the request of the Unidad Administrativa Especial de Aeronáutica Civil (UAEAC, also termed AeroCivil). Earth Satellite Corporation (now known as MDA Federal Inc.) of Rockville, Maryland was selected by AeroCivil through a qualifications based competitive process to provide the requisite technical assistance. Earth Satellite Corporation augmented its staff with a team that includes professional support from the National Center for Atmospheric Research (NCAR) located in Boulder, Colorado and AviaStructure, Inc. of Washington, DC.

Project efforts were initiated in late March 2004 and included site visits, issuance of draft reports, technology transfer seminars, and working meetings with and presentations to AeroCivil management and staff. The EarthSat Team also met with other providers of aviation meteorological data and services and users of this information as part of the development of the overall effort.

A series of five detailed technical reports were submitted by the EarthSat Team through the course of this technical assistance. These reports were subject to rigorous internal review by members of the Team and during the course of intensive working meetings with AeroCivil staff. The reader is referred to these technical reports, that have been previously provided, for additional details that present the findings and rationale for the EarthSat Team recommendations. These reports have been prepared in English and Spanish. Should differences in interpretation surface, the English version should prevail.

The EarthSat Team is indebted to the professional and respectful involvement of the AeroCivil staff. They engaged us in lively dialogue throughout the course of the technical assistance and their active participation contributed to developing a program to improve the content, quality and delivery of aviation meteorological services to users of Colombian airspace and airports. The following individuals representing AeroCivil and the EarthSat Team are recognized:

<u>AeroCivil</u>
Fernando Sanclemente Alzate, Director General
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This Executive Summary provides a snapshot of the technical assistance and is one of the deliverables included in the EarthSat Team project efforts. It succinctly highlights the key issues, concerns, and report findings and recommendations for the benefit of those Colombian officials who have the decision making responsibility and authority to implement the Aviation Meteorological System program. For more detailed discussion of individual issues and specific recommendations, readers should refer back to the EarthSat Team's Working Papers 1 through 5.

2.0 Basic Issues

The provision of meteorological information services to the aviation sector is a critical part of a modern integrated air traffic management system. **Current and forecast weather information improves aviation safety and provides economic benefits to air traffic system users.** Colombia's geographic location with respect to flight routes and its own varied topography and climatological conditions speak to the need for an improved system to acquire and disseminate aviation meteorological data on a near real-time basis. Some 70 percent of the flights between South America and North America cities utilize Colombian airspace. The high humidity that exists over most of the country and the effect of strong orographic influences effect large diurnal changes in the weather. These factors make forecasts of hazardous aviation weather especially important and challenging to produce.

Aviation is an international industry. Aircraft link one country with another to serve the commercial and personal needs of their residents. The International Civil Aviation Organization (ICAO) was formed to establish and promote a common set of international standards associated with all components of aircraft, airport and weather operations and management. The World Meteorological Organization (WMO) also establishes international standards for aeronautical weather systems and has established a World Weather Watch Program. **Colombia is a member of ICAO and WMO, which implies its acceptance to meet international standards or document those situations where such compliance is not viable. Colombia has not filed any notice of any differences between its regulations and procedures and those contained in ICAO and WMO documents. AeroCivil is the national representative to ICAO, and the Instituto de Hidrologia, Meteorologia y Estudios Ambientales (IDEAM) is Colombia's face to**

the WMO. AeroCivil and IDEAM have signed an Inter-Administrative Agreement to serve their respective international roles with regard to the provision of aeronautical meteorological services.

Colombia attempts to fulfill its internal and international responsibilities for aeronautical meteorological services utilizing several resources. Local weather observations of varying quality and degree of adequacy are taken at each of Colombia's 48 controlled airports. Weather observations are taken at some airports by AeroCivil and at others by IDEAM. Automated weather observing systems at certain airports can also generate these reports (METARs). There are no weather radars in Colombia, and satellite imagery is obtained from the Geostationary Operational Environmental Satellite (GOES) operated by the United States National Oceanic and Atmospheric Administration. Colombia also operates a radiosonde network to obtain upper air meteorological data. Other facilities and equipment are deployed throughout Colombia in an attempt to meet international user needs and expectations and are utilized to their available capabilities by AeroCivil and IDEAM staff.

Although the above may suggest that the aeronautical meterological system in place is functioning well and meeting international standards, closer examination by the EarthSat Team identified many deficiencies. Chief among these include, but are not limited to:

1. Airport observing systems are frequently not compliant with ICAO and WMO standards for aviation in terms of either the sensors provided or their location at the airport. RVR and ceilometer systems are not installed at all international airports and airports with ILS systems.

2. Observations, whether taken manually or through automated means, are not being transmitted for dissemination locally, within Colombia, or internationally with the requisite regularity and completeness.

3. The facilities and equipment are not necessarily functioning or being maintained in accordance with their required performance standards or manufacturer recommendations.

4. Upper air soundings are not being taken at all five Colombian upper-air stations and when performed they are not taken at the requisite frequency. This significantly degrades Colombia's ability to issue adequate forecasts over Colombian airspace.

5. Colombia does not issue AIREPs or SIGMETs.

6. Colombia does not adequately combine and integrate airport observations with other meteorological information to give forecasters and pilots an adequate situational awareness of the location and evolution of Colombian weather systems that may affect the safety of aircraft operations, and of the development of these phenomena in time and space. Improvements will require more

advanced forecasters' workstations based on graphical products and better use of satellite data sets, perhaps augmented by weather radars or lightning detection systems.

7. Pre-flight pilot briefings are limited and lack the detail needed for efficient flight planning purposes. More use needs to be made of graphical products instead of text messages. Some airlines are now contracting for their own support from foreign private companies.

8. Communication links within the Colombian aviation weather network have insufficient capacity to handle current and potential future data and graphic transmission activity.

9. Despite a dedicated staff of AeroCivil and IDEAM employees, little attempt has been made for increased training and automating tasks so that more time and effort can be given to data interpretation and analysis.

10. The Inter-Administrative Agreement between AeroCivil and IDEAM is in litigation and not yielding the intended outcomes. This is causing internal conflicts and resulting in a less than satisfactory level of service to system users.

In sum, Colombia is not meeting its ICAO and WMO signatory obligations and commitments, and is not using its existing aviation meteorological system to fullest potential. Improved weather services will improve the safety, efficiency, and international reputation of the Colombian aviation system.

3.0 Approach to Solutions

The EarthSat Team has sought to present a phased development plan consistent with relevant ICAO and WMO standards. **Our perspective suggests that the critical issue is one of not just meeting minimum international standards, but providing a level of service for the entire Colombian aviation community where improved weather information will have a direct impact on flight safety and efficiency.** This encompasses a need for improved observational systems, and increased numbers of trained meteorologists and maintenance providers as part of a cost-beneficial solution. Improvements to aviation meteorological services will be of benefit to airlines, pilots, dispatchers, and those engaged in air traffic management. It is also desirable to extend the notion of international standards to embrace domestic flights and aircraft activity.

We expect the plan will reflect a transition to the increased use of automation in the current meteorological system, from observations to data distribution, analysis, product generation, and dissemination to end users. Introduction of automated, self-service weather briefing stations could, for example, open these services to every airport in Colombia. This transition is fully consistent with future enhancements expected from the meteorological components of the planned communications, navigation, surveillance/air traffic management (CNS/ATM) improvements that provide for more data, fully networked communications links, data access, and enhanced visualization and display of weather products.

The EarthSat Team developed a series of major goals and objectives of a modernization plan for the aviation meteorology system. These include:

1. Collection and dissemination of hourly weather reports (METARs) from all controlled airports using upgraded automated weather stations that provide observations around the clock

2. Use of networking technologies to eliminate multiple manual data entries and improve dissemination.

3. Issuance of aviation weather forecasts (TAFs) for all controlled airports.

4. Issuance of AIREPs and SIGMETs to enhance situational awareness and enhance flight safety.

5. Improve the availability and use of upper air observations from radiosondes.

6. Expand and improve the use of remote sensing technologies for situational awareness.

7. Transition existing staff responsibilities from routine observational tasks to the production and delivery of higher level meteorological services.

8. Develop a Colombian mesoscale numerical weather forecasting model for use in preparing TAFS.

4.0 Technical Options

Irrespective of the technical options developed and evaluated to implement the recommended Colombian Aeronautical Meteorological System and meet the goals and objectives listed above, it was determined that any solution would share the following similar characteristics:

1. **Establishment of a Colombian Aeronautical Meteorological Center (CAMC)** to serve as a numerical forecast computing center, meteorological watch office and provide flight service station services. The CAMC is the heart of the aviation meteorological function and employs meteorologists to receive and interpret the flow of incoming data for the generation of weather products and services such as METARs, TAFs, AIREPs and SIGMETs. The CAMC would be Colombia's link to the international aviation weather community by transmitting, receiving and disseminating data, graphical imagery and weather products. Staffing levels at the CAMC are dependent on the scale of the technical option that is selected for implementation.

2. **The purchase of high quality meteorological systems and budgeting adequate funds for their maintenance.** Acquisition decisions should be based on demonstrated system capabilities and reliability as evidenced by prior sales and certification testing by the United States Federal Aviation Administration or other national meteorological or testing agencies. Life-cycle costs that include the initial as well as on-going maintenance expenses are the more relevant considerations in the acquisition process.

3. **Acquisition of automated surface meteorological systems (AWOS)** that provide real-time measurements of temperature, dew point, wind speed and direction, ceiling and forward visibility. Additional sensors to provide present weather (type of precipitation) and lightning detection may be desirable at certain airports. These systems have been deployed at airports across the globe and have proven to be highly effective in generating observations on a continual basis, thereby allowing observers more time to focus on data interpretation, generation of derivative weather products and services, and communication with users.

4. **Implementation of a continuous training program** for observers, meteorologists, forecasters, flight service station and maintenance staff to enhance productivity and create opportunities for career advancement and development.

The EarthSat Team summarized our recommendations into three basic technical options that encompass the above factors and that are differentiated by the extent of the facilities and equipment to be acquired for deployment over a ten-year period.

Technical Option 1 provides a "core" set of systems that includes:

- Acquisition of 16 AWOS units at those airports serving international aircraft operations and equipped or planned to be served with an instrument landing system and having relatively high levels of aircraft activity (in excess of 20,000 annual movements.)
- Runway visual range (RVR) and ceilometers for each instrument landing system runway
- Expanded radiosonde and upper air soundings program
- GOES receiving station
- World area forecast system (WAFS) workstation
- Forecaster workstations
- Software templates for AIREPs and SIGMETs
- Pre-flight briefing system including software
- Local airport pre-flight briefing workstation
- Weather systems for calibration and training
- Modernization and increased capacities of electronic data communication links

Because Technical Option 1 addresses only 16 of the 48 controlled airports in Colombia, it is not compliant with ICAO standards. This option is presented to provide a low-cost solution in the event funding is restricted.

Technical Option 2 expands Technical Option 1 to all 48 controlled airports in Colombia.

Technical Option 3 builds on Technical Option 2 and includes other aviation weather equipment and facilities such as a national lightning detection network, windshear detection and modeling systems, mesoscale numerical modeling program, and weather Doppler radars.

The costs to implement any of these three technical options, including allowances for installation, annual maintenance, and recommended consultant services are:

- Technical Option 1 – US$12,845,710
- Technical Option 2 – US$17,902,550
- Technical Option 3 – US$35,776,550

It is important to note that while Option 3 combines a number of separate systems that were discussed in Working Paper Number 2, these systems could be implemented separately and do not have to be included in a development plan on an "all or nothing" basis. Some of these optional systems, for example, would be necessary to meet the EarthSat Team's major goals and objectives of a modernization plan for the Colombian aviation meteorology system.

5.0 Organization and Management Options

The current method of delivering aviation weather data and services in Colombia is dependent on shared management and responsibility between AeroCivil and IDEAM. It is not unusual for a country to have separate weather agencies, one within a civil aviation authority and another as the main meteorological agency. However, in most countries, one entity provides the aeronautical meteorological services. Colombia is unusual in that the provision of these services is allocated between two agencies, with each performing specific services on an airport-by-airport basis. **This has led to a parallel organizational structure with considerable duplication of components. This situation is exacerbated as neither AeroCivil nor IDEAM take full responsibility for the aeronautical meteorological program. The EarthSat Team has concluded that the existing Inter-Administrative Agreement between these agencies is not sufficiently detailed to permit the identification of clear lines of authority and responsibility.**

The EarthSat Team reviewed the organization and management programs implemented in other countries and identified four alternative arrangements that could be emulated in Colombia and achieve establishment of a CAMC. The four options included:

1. Maintain the existing agreement between AeroCivil and IDEAM.

   The existing agreement falls short in addressing key features that provide for a successful dual-agency fulfillment of international aviation meteorological commitments. The agreement does not adequately address deliverables, frequency and timing of information, standards to be followed, performance measures, payment schedules and a dispute resolution procedure. Continued reliance on the current agreement is not recommended and a new arrangement should be developed.

2. Negotiate a new agreement between AeroCivil and IDEAM that follows the United States or Canadian model.

   This second option elevates aviation meteorological services within IDEAM to meet international needs and expectations by having that agency responsible for upper air soundings and forecasting. In this case, responsibility for providing and maintaining the basic airport observing systems and staffing the observation function could be assigned to AeroCivil, and IDEAM employees could be transferred to AeroCivil to carry out the observation role. The staffing and operation of the CAMC could be assigned to IDEAM.

   A clear division of responsibility is needed to simplify the full integration of the meteorological systems into the airport infrastructure, communication links and operational support. The United States or Canadian models offer some guidance to implementing this option. The United States model would provide for AeroCivil to retain the surface observation and flight service station program and identify which services IDEAM would provide. Under the Canadian model, all airport observations would stay with AeroCivil and all other services would be provided by IDEAM. It is noted that the United States has recently contracted the flight service station function to private industry, thereby diminishing the differences between the United States and Canadian models.

3. Concession the acquisition and dissemination of aeronautical meteorological data and services to a third-party, such as a private entity or another government agency.

   The option of concessioning the operation of the aeronautical meteorological service program to a third-party could be assigned to AeroCivil. It was envisioned that this concession **would operate for a five-year period and then revert to full operation by AeroCivil.** The concession could be similar to the New Zealand or European model whereby the delivery of meteorological services is performed by a private company on a for-profit basis. During the transition period, AeroCivil could acquire and maintain the equipment necessary and have the contractor train AeroCivil employees to assume the on-going aeronautical weather services program.

4. <u>AeroCivil assumes responsibility for delivery of the aeronautical meteorological system.</u>

   The option to have AeroCivil assume total control of the aeronautical meteorological services requires staff and equipment transfers from IDEAM. The radiosonde program could remain with IDEAM in keeping with its designation as Colombia's representative to the WMO. The planning, design and implementation of new aviation meteorological service by a single entity is facilitated under this arrangement. **This approach also eases the integration of the required systems and communication links with other airport services provided by AeroCivil.**

6.0 Benefit/Cost Analyses

The evaluation and selection of a preferred course of action to implement an improved aeronautical meteorological services program followed a stepwise approach utilizing benefit/cost analyses. The basis for these benefit/cost analyses follow evaluation procedures prescribed by ICAO. First, the preferred technical option is identified. Second, the organization and management options are evaluated for the preferred technical option.

Selection of the preferred technical option considered the following factors:

1. Equipment establishment and maintenance costs

2. Personnel costs

3. Benefits associated with:
   - Automation of surface weather observations
   - Enhanced aircraft safety
   - Staff productivity
   - Operational efficiencies
   - Traveler time savings

The resulting benefit/cost ratios, expressed as (US$ benefits per US$1 of implementation costs) were:

Technical Option	Benefit / Cost Ratio
Option 1	180:1
Option 2	347:1
Option 3	247:1

The options all realize very positive benefit/cost ratios, far in excess of the 1.00 that a traditional benefit/cost analysis seeks to yield in order to find a particular solution cost-beneficial. This outcome is due in part to the devastating costs associated with aviation accidents in terms of loss of life and aircraft. Even on the basis of efficiency and normal operating costs, the implementation of the aeronautical meteorological system improvements outlined in Technical Option 2 or Technical Option 3 is cost-beneficial. **Because Technical Option 2 yields the highest ratio, it is the most appealing and preferred technical option. Technical Option 2 provides for improving weather observations and the dissemination of METARs and TAFs at all 48 controlled airports and the full core set of system upgrades.** Technical Option 3 is the most expensive to pursue and its resulting benefit/cost ratio reflects the diminishing rate of return that the additional aviation meteorological services and products yield to users. Individual enhancements included in Technical Option 3, however, would provide significant enhancements to the Colombian Aeronautical Meteorology System and may be evaluated on an individual basis during the implementation of the overall system plan.

The benefit/cost ratios developed for the organization and management options are presented below:

Organization and Management Option	Benefit / Cost Ratio
Maintain Status Quo	0
Renegotiate AeroCivil – IDEAM Agreement	
United States Model	317:1
Canadian Model	328:1
Concession Operation	204:1
AeroCivil Operation	209:1

These options were evaluated for their costs of initial establishment and on-going maintenance expenses, and the benefits outlined above. **With the exception of the maintain status quo, or do nothing, option, each of the benefit/cost ratios reflect solutions that offer substantial value to Colombia.** The action options may be categorized in two sets, each with benefit/cost ratios in the 200's or low 300's. The primary reason for the comparatively lower ratios for the concession and total AeroCivil operations is the increased personnel costs borne by AeroCivil and AeroCivil's extra costs for managing the concession operation.

A renegotiation of the AeroCivil-IDEAM agreement is recommended as the preferred organization and management option because it yields the highest benefit/cost ratio. Implementation of this option is, however, dependent on a successful negotiation process that clearly defines the roles, responsibilities, payments, dispute resolution and penalties associated with the delivery of the aeronautical meteorological data and services in accordance with ICAO standards.

7.0 Funding Options

ICAO and WMO have provided signatory countries with models to establish cost recovery programs to fund the acquisition and delivery of aeronautical meteorological services. These models take into consideration the following factors and were utilized by the EarthSat Team in its evaluations:

1. The equipment and staffing requirements of the requisite aeronautical meteorological services program.

2. The costs to establish and maintain the program.

3. Cost sharing opportunities with other meteorological entities.

4. An activity-based means of distributing costs across different classes of users (origin-destination flights and overflights) in the aviation sector.

5. Fair value of the aeronautical meteorological services and products to be recovered.

Given the 10-year cost of establishing and continuing the aeronautical meteorological service program envisioned in Technical Option 2 and following the Canadian model for an AeroCivil-IDEAM agreement as the preferred organization and management option, three funding alternatives were evaluated:

1. Use of an up-front loan from a commercial bank or multilateral lending agency.

2. Borrow funds from a commercial bank on an as-needed basis.

3. Self-funding from net operating income.

Each funding option provides for a cost recovery methodology and program as prescribed by ICAO. **A critical element to implement cost recovery is the designation of a fund in which all monies received may be deposited for use in establishing and operating the aeronautical meteorological services program. Colombia currently lacks such a fund account.** The total capital requirement of approximately US$18 million is insufficient to attract multilateral lending agencies such as the Inter-American Development Bank. Such institutions generally seek projects that require upwards of US$25 million in order to achieve acceptable economies of scale for program administration and monitoring. The recommended aeronautical meteorological program would need to be combined with other types of projects to enhance aviation services in order to pursue such funding.

A cash flow analysis of the combined use of cost recovery fees and an up-front loan of US$8.6 million suggests that this amount is sufficient to start the program and develop a large surplus. By year six of the program, these fees are sufficient to generate a surplus that can be used to implement portions of Technical Option 3 and thereby further improve the extent of aeronautical meteorological services to users.

Borrowing as-needed based on a cycle of US$2.6 million in year 1, US$3.5 million in year two results in a constant user fee schedule and supports upgrades to the aeronautical meteorological system in year six. A more cost effective version of this scenario is for

AeroCivil to replace the loans with funds from their annual budget, eliminating the need for interest payments and reducing the user fees below those of the self-funding option.

Self-funding enables AeroCivil to implement the recommended core system of aviation weather services and products without a change to the user fee rates and generates a surplus in year six of the program.

The EarthSat Team determined that the user fees required for each of the scenarios results in the landing fees listed in the table below:

Financing Option	Operations Fee	Overflight Fee
Up-front Loan	$3.57	$3.77
Borrow as Needed	$3.34	$3.53
Self-Funding	$2.79	$2.95

The final report deliverables to AeroCivil contain the set of spreadsheets used to derive the financial data and develop the cost recovery program. These spreadsheets can be updated by AeroCivil depending on more detailed data for system costs and benefits available through internally-generated analyses or through a competitive bidding process.

It is important to recognize that accumulation of surplus funds as part of a recovery program is acceptable under ICAO policy and guidance provided that such surplus funds are set aside for the establishment, staffing and maintenance of aeronautical services to those paying users of the system.

The EarthSat Team recommends that the "borrow as needed" option be pursued by AeroCivil and that a cost recovery fee structure and dedicated fund be established to implement the recommended aeronautical meteorological system. Surplus funds collected as part of the cost recovery program should be utilized to implement those components of Technical Option 3.

8.0 Environmental Considerations

A review of the environmental impacts and consequences of the recommended aeronautical meteorological system was conducted by the EarthSat Team. The review concluded that the recommended facility improvements do not generate adverse impacts on the natural or human environments.

The potential use of solar power for meteorological sensors was examined and determined to be practical for many sensors, but solar power should not be substituted for adequate airport power systems for all controlled airports. For reliable airport operations it is essential to implement a plan that includes upgrades to line power with backup generators and modern communication links.

9.0 Recommendations

The EarthSat Team recommends the following:

1. Technical Option 2 should be implemented over a 10-year time frame with periodic program reviews to update and adjust priorities to reflect funding realities, technological advances, and changing operational requirements.

2. The current Inter-Administrative Agreement between AeroCivil and IDEAM should be terminated and a new agreement negotiated stating specific performance, accountability, monitoring and enforcement measures.

3. A cost recovery system involving landing fees and overflight fees should be established in accordance with ICAO policies and guidance. A dedicated fund account that is utilized only for the purposes of implementing the improvements for which such cost recovery funds are collected should be established. These funds may also be used for projects that contribute to enhanced flight safety and efficiency in Colombia.

4. The recommended aeronautical meteorological program should be funded with loans taken as needed in the first two years or, alternatively, from the operating budget of AeroCivil.

In the event a binding and enforceable Inter-Administrative Agreement cannot be negotiated with IDEAM within a reasonable time schedule (one year), AeroCivil should undertake the responsibility of establishing, operating and maintaining the aeronautical meteorological system with its own resources. This course of action is best facilitated through the concession of the system to a third-party for a five-year period. This time frame enables AeroCivil to staff and train for the transition. AeroCivil should fund the facilities and equipment costs, including those associated with a CAMC and communication links. This arrangement requires the concessionaire to only provide staffing and training services.

AeroCivil should give every consideration to United States firms and businesses in implementing the recommended aeronautical meteorological system. This is in keeping with AeroCivil's agreement with the United States Trade and Development Agency as part of receiving grant funds for the conduct of this study. A listing of United States firms and businesses that offer services and products associated with the types of facilities and equipment recommended for establishment is provided in the technical and final report documents.

The EarthSat Team is available to assist AeroCivil in implementing the recommended program. We believe in and are committed to our recommendations and ready to offer our services to see them successfully implemented.

Working Paper Number 1

ASSESSMENT OF CURRENT INFRASTRUCTURE OF THE COLOMBIAN AERONAUTICAL METEOROLOGY SYSTEM

Prepared for

Unidad Administrativa Especial de Aeronáutica Civil
Aeropuerto El Dorado
Bogotá, Colombia

by

Earth Satellite Corporation
Peak Weather Resources
National Center for Atmospheric Research

July 2004

EARTHSAT

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1 Introduction

1.1 Background to the study

The provision of meteorological information services to the aviation sector is a critical part of a modern, integrated air traffic management system. It is well known that a large fraction of airport traffic delays are a result of weather, and that weather also plays a significant role in aircraft accidents. The importance of timely, accurate weather information to aviation end-users such as pilots, airline dispatchers, and en-route, approach, and tower traffic controllers has been well documented in a large number of reports. Improved weather information is expected to both improve aviation safety and provide economic benefits to the air traffic system users.

In Colombia, the Unidad Administrativa Especial de Aeronáutica Civil (UAEAC, also termed AeroCivil) is the cognizant civil aviation authority. The UAEAC shares the responsibility for the provision of aeronautical weather information with the Colombian national weather service, IDEAM (Instituto de Hidrología, Meteorología y Estudios Ambientales), through a signed interagency agreement. Over the last several years plans have progressed in Colombia for a transition to new communication, navigation, and surveillance technologies (CNS/ATM) that will meet the demands of current and future air traffic levels and safety standards. The concepts of CNS/ATM will permit aircraft to fly in any type of airspace, and operate with reduced separations in existing airspace. Given that such a system will place higher demands on the availability of accurate, easily available, real-time weather information and weather forecasts, AeroCivil is aware of the need to modernize its aeronautical meteorological system, and has requested assistance in developing a prioritized ten-year plan to accomplish this.

As a result of these events, EarthSat entered into an agreement with UAEAC to provide Aeronautical Meteorology System Technical Assistance to the Government of Colombia. The agreement was funded through a grant to UAEAC from the U.S. Trade and Development Agency. Program funding was received by EarthSat in April, with the official start of the project being April 23, 2004. The EarthSat team made its first visit to Colombia the week of March 29. This early kick-off meeting was accompanied by site visits and discussion with local personnel in order to gather data on the current status of the aeronautical meteorological infrastructure. A second visit during the week of May 24 completed the on-site data gathering phase. In the present report, Working Paper Number 1, the results of the consultants' evaluation are presented.

1.2 Colombia background

Colombia is the fifth largest economy in Latin America, with a gross domestic product of US$81.2 billion.[1] Transportation and communication are among the Colombian

[1] The background statistics in this section were obtained from the Web page of the Colombian Embassy in Washington, D.C., with economic data from 2001.

economic sectors showing the largest annual rates of growth, 3.36% (adjusted for inflation).

Colombia has a diverse geography. Three mountain chains of the Andes divide the country, with 70% of the population living in the mountainous areas. The southern and eastern regions of Colombia are part of the Amazon basin with dense tropical forests that gradually change to broad plains and grasslands as one moves towards the northeast. The northern coast is on the Caribbean, while the western coast is on the Pacific Ocean.

Colombia was the first country in North or South American to have a commercial airline. The company, Sociedad Colombo-Alemana de Transporte Aéreo, was founded in 1919, and later became Avianca. Aviation remains very important to Colombia, and the country has a healthy domestic airline and air cargo service. The mountainous terrain, a limited system of roads, and years of civil unrest make air travel and air transport a necessity. Colombia has almost 600 officially recognized civilian airports. UAEAC was established in 1994 to direct the development of airports in the country. UAEAC currently supports and maintains 47 controlled airports, with one additional controlled airport operated by the El Correjón coal mine — one of the largest open pit coal mines in the world. Colombia also has 47 heliports. Forty-five (45) of the UAEAC-controlled airports take hourly weather observations (METARs) and provide meteorological (MET) services to pilots and airlines.

The Government of Colombia is currently undertaking a multi-year, comprehensive strategy that aims to revitalize the economy, strengthen government institutions, and bring about a lasting peace by reducing the production of illegal drugs. This is known as Plan Colombia. Plan Colombia is primarily funded by internal Colombian funds, with outside assistance from the United States, the United Nations, and several other countries.

Plan Colombia is supporting a number of airport projects, primarily runway rehabilitation and repaving, as well as the construction of one new airport (Vigia del Fuerte). The airport projects being supported by Plan Colombia are summarized in Table 1.1. With the exception of Bahía Solano, which is already a controlled airport, all of the airports being upgraded under Plan Colombia are small, uncontrolled airports. After completing its runway repair, one additional airport (Puerto Inírida) is expected to be upgraded to controlled status and will provide MET services.

1.3 Major flight routes and air traffic volume in Colombia

Colombia is located at a critical spot in South America, with some 70% of the flights from Central and North America crossing Colombian territory on their way to other South American destinations. These flight operations involve aircraft from a large number of countries, so it is important to maintain a common set of international standards for aeronautical meteorology. Typical over-flight routes from the southeast, such as those from Brazil and Argentina, pass over Leticia in the south of Colombia toward San Andreas in the Caribbean northwest of the Colombian mainland, and then proceed northbound to Miami. Flights originating in countries to the south, such as Ecuador, Peru, and Chile, tend to over-fly the western border of Colombia.

Table 1.1
Airports for Peace, funded by "Plan Colombia"

Year 2003 Aeropuertos para la Paz				
City/Village	Department	New RWY	RWY Maintenance	ATC Control
Acandí	Chocó		Paving	
Timbiquí	Cauca		Paving	
Puerto Inírida	Guainía		Paving	Anticipated

Year 2004 Aeropuertos para la Paz

City/Village	Department	New RWY	RWY Maintenance	ATC Control
El Bagre	Antioquia		Paving	
Frontino	Antioquia		Paving	
Vigia del fuerte	Antioquia	Construction		
Bahía Solano	Chocó		Paving	YES
Pizarro - Bajo Baudó	Chocó		Paving	
La Macarena	Meta		Paving	
Tarapacá	Amazonas		Paving	
La Pedrera	Amazonas		Paving	
El Charco	Nariño		Paving	
Barranco Minas	Guainía		Paving	
Malaga	Santander		Paving	

Year 2005 Aeropuertos Comunitarios

City/Village	Department	New RWY	RWY Maintenance	ATC Control
La Chorrera	Amazonas		Paving	
Barbosa	Santander		Paving	
Zapatoca	Santander		Paving	
Muzo	Boyacá		Paving	
Encanto	Amazonas		Paving	
López de Micay	Cauca		Paving	
Puerto Rondón	Arauca		Paving	
Araracuara	Caquetá		Paving	

Table 1.2 summarizes the number of commercial aircraft that passed through Colombian airspace (without landing or takeoff in Colombia) in the years 2000-2003.

Table 1.2 Over-flights of Colombia by En-route Aircraft

Año	2000	2001	2002	2003
Total per year	49,961	52,805	51,934	51,909
Daily mean	137	145	142	142
Daily mode	140	141	146	141

Flight data provided by UAEAC

In Colombia there are also a substantial number of domestic flights that navigate over the widely varying topography and through diverse and occasionally hazardous weather conditions both at the surface and at flight altitude.

Table 1.3 summarizes the number of flight operations for each of the 47 airports controlled by AeroCivil in the years 2000-2003. The airports are divided into AeroCivil's six operational regions, with the airports in each region listed in descending order of annual number of flight operations based on 2003 data. Traffic levels have been relatively constant in the past four years despite the effects of terrorist events in other parts of the world and the economic turndown. The vitality of the domestic aviation activity is highlighted by the approximately 900,000 domestic operations per year, which is about 20 times the number of over-flights by international aircraft.

The data in Tables 1.2 and 1.3 suggest that Colombian air traffic volumes are currently stable rather than increasing, presumably a reflection of the current economic downturn and international terrorism. As the global economic situation improves, it is expected that air traffic will resume its anticipated growth, as forecast in various studies discussed next.

Many aspects of a country's civil aviation infrastructure are critically dependent on the air traffic density that has to be supported. Accordingly, ICAO has developed recommended procedures for forecasting future traffic trends. In 2002, there was a meeting of the CAR/SAM Traffic Forecasting Group in Lima, Peru (5-9 August 2002). Overall, this meeting concluded that passenger traffic within the region (including flights into or out of the region) could be expected to grow at an average annual rate of about 4.5 percent in the years out to 2012, while the average annual growth in aircraft movements would be a bit less at about 4.0%.

As part of their 2003 review of AeroCivil's non-meteorological responsibilities, Innovative Solutions International (ISI, 2003) suggested that air traffic movements may grow at an even slower rate (2.5 to 4.1%) in the years out to 2010. This analysis reflects the current global economic slowdown, the war in Iraq, the recent SARS epidemic, and other negative indicators that will limit the short-term growth in civil aviation.

Table 1.3 Number of flight operations (takeoff or landing) at each controlled airport, grouped by region

Region		Airport	2,000	2,001	2,002	2,003
Antioquia	SKMD	MEDELLIN	81,441	75,533	84,992	82,426
	SKRG	RIONEGRO	35,476	39,853	44,090	45,113
	SKUI	QUIBDO	12,098	11,204	11,787	13,002
	SKMR	MONTERIA	11,857	9,727	11,872	12,012
	SKLC	CAREPA (Los cedros)	9,207	8,896	10,371	11,504
	SKMZ	MANIZALES	9,760	8,719	8,679	9,831
	SKBS	BAHIA SOLANO	3,993	4,134	3,878	4,057
Atlantico	SKCG	CARTAGENA	33,060	32,395	33,357	31,634
	SKBQ	BARRANQUILLA	32,138	28,773	28,662	26,559
	SKSM	SANTA MARTA	13,947	13,349	13,078	12,768
	SKSP	SAN ANDRES	12,478	12,659	12,190	12,153
	SKVP	VALLEDUPAR	7,354	8,374	8,402	6,635
	SKCZ	COROZAL	4,006	3,608	3,694	4,848
	SKPV	PROVIDENCIA	3,516	3,142	3,282	3,132
	SKRH	RIOHACHA	2,536	2,531	2,292	2,176
Bogota	SKBO	BOGOTA D.C.	199,490	206,348	202,938	195,734
	SKGY	GUAYMARAL	71,474	76,437	66,796	60,472
	SKGI	GIRARDOT	11,077	12,656	16,942	19,360
	SKIB	IBAGUE	23,176	35,200	23,290	18,658
	SKNV	NEIVA	22,400	19,994	20,508	18,193
	SKQU	MARIQUITA	6,432	23,468	25,337	17,725
	SKAS	PUERTO ASIS	7,783	6,658	6,621	6,900
	SKFL	FLORENCIA	6,483	7,887	9,412	6,688
	SKSV	SAN VICENTE DEL CAG	1,014	718	1,421	3,046
	SKLT	LETICIA	2,263	2,343	2,644	2,640
Valle	SKCL	CALI	55,439	48,380	50,529	46,279
	SKPE	PEREIRA	24,520	26,555	24,608	22,199
	SKAR	ARMENIA	9,035	9,875	10,845	10,739
	SKPS	PASTO	6,099	6,184	7,344	7,646
	SKPP	POPAYAN	5,942	5,054	5,499	7,458
	SKCO	TUMACO	1,922	2,867	3,957	5,715
	SKCO	CARTAGO	4,719	4,479	4,385	3,298
	SKIP	IPIALES	1,933	1,783	1,474	1,396
	SKGP	GUAPI	1,758	1,236	1,214	1,152
	SKBU	BUENAVENTURA	2,213	1,294	1,162	1,034
Santander	SKBG	BUCARAMANGA	36,947	34,685	29,444	27,614
	SKCC	CUCUTA	15,803	17,200	16,755	15,056
	SKEJ	BARRANCABERMEJA	9,782	8,974	7,414	10,157
	SKUC	ARAUCA	10,759	8,942	9,535	9,878
	SKSA	SARAVENA	5,905	7,187	5,521	5,905
	SKTM	TAME	1,483	3,162	3,607	2,945
	SKOC	OCANA	1,982	1,494	1,350	879
Meta	SKVV	VILLAVICENCIO	42,964	43,452	45,026	39,828
	SKYP	EL YOPAL	27,454	31,480	32,848	29,967
	SKSJ	SAN JOSE DEL GUAVIAI	19,300	18,774	22,659	16,047
	SKMU	MITU	6,206	5,252	5,695	5,463
	SKPC	PUERTO CARRENO	1,126	652	1,248	822
			917,750	**943,567**	**948,654**	**898,743**

If we accept 2.5% as a low estimate at the growth rate, and 4.1% as a more optimistic higher estimate of the possible growth rate, we find the results shown in Table 1.4 below. The table shows estimated growth in the total number of domestic flight operations at controlled airports plus over-flight operations (note that there are another about 13,000 operations at ten uncontrolled airports reported by UAEAC; i.e., about 1% of the numbers shown in Table 1.4).

Table 1.4 Growth in total air traffic operations based on two different estimates of annual growth (2.5% and 4.1%)

Year	Low Growth	High Growth
2003	950,652	950,652
2004	974,418	989,629
2005	998,779	1,030,204
2006	1,023,748	1,072,442
2007	1,049,342	1,116,412
2008	1,075,575	1,162,185
2009	1,102,465	1,209,834
2010	1,130,026	1,259,438
2011	1,158,277	1,311,075
2012	1,187,234	1,364,829
2013	1,216,915	1,420,787
2014	1,247,338	1,479,039

It can be seen from this table that in the ten years leading up to the year 2014, the air traffic volume is expected to increase in the range of 28 to 49%, based on the low and high growth rates estimated by ISI.

The effect of this anticipated growth on the aviation system in Colombia was modeled by ISI (2003). They found that even with a 50% increase in traffic, the average flight times and delay times would not be significantly affected. Thus, it appears that the airspace system in Colombia has sufficient capacity to meet the gross demands of the system out to 2014. However, it should be noted that the ISI study did not include the effects of weather, and so is somewhat peripheral to the major concern of this report. Here we may conclude that any inefficiencies, delays, and weather safety concerns that currently exist in the system will be magnified proportionally by an increase in air traffic volume.

1.4 Weather issues affecting aviation in Colombia

The objectives of aeronautical meteorology are to support the air traffic control function (tactical control), the traffic management function (strategic planning), to provide services to pilots in-flight and preflight, and to support other users such as dispatchers and airport operators. To accomplish these objectives, appropriate weather information must be available, and it must be presented in a form that is best suited to the individual user's mission need.

Weather adversely affects the efficiency of aviation operations by hindering the ability to meet the demand for capacity at airports and in the en-route airspace. In the United States, the primary cause of delays of 15 minutes or higher is consistently weather, which accounts for 65 – 70% of these delays. With respect to safety, data from the U.S. National Transportation Safety Board indicate that weather is a factor in nearly 23% of all accidents.

There are a variety of weather phenomena that affect aviation operations in most countries of the world. These include thunderstorms, heavy rain, reduced visibility and fog, low ceiling, turbulence, low-level windshear, volcanic ash, icing, and hail. Some of these phenomena are inherently dangerous to flight, like thunderstorms and turbulence. Other phenomena like reduced ceiling and visibility are primarily important because they reduce flight operations at airports. They are also a major factor in accidents such as Controlled Flight into Terrain.

The geography of Colombia is quite varied. Tropical conditions exist in the north part of the country and the Caribbean, mountainous regions with high valleys associated with several mountain chains that are oriented roughly northeast-southwest through the central part of the country, and tropical lowlands and jungle over the large southeastern part of the country. This general physiography is illustrated in Fig. 1.1, which also shows a number of important cities/airports where METARs and other climatological information are recorded.

With the high humidity that exists over most of the country and the strong orographic influences, the diurnal changes in weather are very large, and weather forecasting is a particularly important as well as particularly challenging problem. All the weather phenomena listed above impact aviation in Colombia, though icing and hail are regarded as being of generally less importance. The following subsections discuss the principal Colombian weather hazards in rough order of perceived importance, with some discussion of their geographic and seasonal distribution.

Information from Website of IDEAM

Figure 1.1 Map of Colombia illustrating topographic variations and the location of principal airports. Note that the position and size of the islands of San Andrés and Providencia are not shown to scale.

1.4.1 Reduced ceiling and visibility

Reduced ceiling and visibility is a problem all over Colombia in association with heavy rain and thunderstorms. However, there are a number of airports that are particularly impacted by fog, mist, and drizzle associated with the diurnal cycle of cooling that produces low cloud and fog in the early morning hours. The airports of Bogotá, Guaymaral, Rionegro, and Medellín are in this category. At Rionegro, for example, there are about 5-10 days of fog (visibility < 1,000 m) per month throughout the year, with only weak month-to-month variability. There are 15-27 days per month with mist.

In Bogotá there is a strong annual trend. The number of fog days per month has a minimum of 1-2 in the June-August period, with a maximum of 10-12 days per month in December and January. There are on average 9-25 days per month with mist, with the same annual trend noted for fog.

The incidence of fog is much less in other parts of the country, with typically only a few days per month with fog. In the rainy period of October-November, for example, Barranquilla records 3 days per month with fog on average.

The airports strongly affected by fog (Bogotá, Guaymaral, Rionegro, and Medellín) are quite busy, and are important parts of the national airspace system in Colombia. If the El Dorado airport in Bogotá is closed for an hour or two with fog, for example, this delay can ripple through the system affecting air traffic in the country for much of the day. As noted earlier, cloudiness and reduced visibility is one of the most common weather factors in fatal accidents not only in Colombia, but worldwide.

1.4.2 Heavy rain, thunderstorms, and tropical storms

The annual trend of rainfall in Bogotá is typical for the central mountainous part of the country, including also Medellín, Cali, and to some extent Pasto. This trend shows two maxima. The first is in the March-May period, and the second from September through November. The monthly precipitation varies from 25 mm to about 110 mm in Bogotá, but with averages roughly twice this amount in Medellín and Pasto. These stations all receive their rainfall on some 15-20 days per month during the rainy season.

Quibdó is one of the rainiest places in the world, with precipitation totals of 550 to 850 mm per month. The minimum occurs during February and March. Precipitation is recorded on about 25 days per month throughout the year, dropping only slightly to an average of 22 days in February and March. The thunderstorm frequency is high from April through October, averaging 10-12 days per month.

In the Caribbean, San Andrés has a maximum in precipitation and thunderstorm days in the months of September-November, with a somewhat lower maximum from June-August and a minimum January to April. San Andrés averages 7 thunderstorm days a month from June through October, and Cartagena, on the mainland, has numbers about twice this large.

Hurricanes usually stay north of the Colombian mainland, but can occasionally affect the coast of northern Colombia with strong winds (Cartagena and Barranquilla). Every 5-8 years on average the Caribbean islands of San Andrés and Providencia are impacted by tropical storms and hurricanes that can shut down the airports for extended periods.

Heavy precipitation is also recognized as an important problem at Cali, Villavicencio, Bucaramanga, and Cúcuta. In the eastern part of the country the precipitation tends to have a strong maximum from May through August and a pronounced minimum from December through March. In contrast, in the south of the country Leticia has a pronounced precipitation minimum in June, July, and August as the Inter-tropical Convergence Zone moves northward.

Lightning from thunderstorms can also be a significant safety issue both for airport staff as well as aircraft en route. One may note that the heavily populated mountainous areas in Colombia have one of the highest frequencies of cloud-to-ground lightning strikes anywhere in world.

Airports are often closed during heavy rain and thunderstorm activity. The heavy rain, of course, leads to a reduction in visibility (and sometimes ceiling). The strong winds, lightning, and low-level wind shear are also hazards associated with heavy rainstorms as a consequence of local convection.

1.4.3 Strong winds and windshear

Strong, gusty winds are recognized as a problem at Cartagena and Barranquilla on the north coast, and at Leticia in Amazonas. Cúcuta and Bucaramanga also report problems with strong winds and turbulence around the airport.

Windshear is known to be a particular problem at two airports, Pasto and Providencia. The acquisition of windshear detecting equipment is currently being considered by UAEAC to mitigate this hazard. The visits of the EarthSat team to these airports confirmed that the problem is one of terrain-induced windshear and turbulence; it is not believed to be of a convective origin. This finding impacts the decision regarding what kind of equipment and algorithms would be appropriate at these airports (see discussion in Section 4.8.2).

1.4.4 Turbulence

Turbulence at en-route flight levels is a result of both convective storm activity and clear-air turbulence. Both are commonplace in Colombia.

The mountain regions of the country are well known for producing mountain waves and other forms of turbulence that are commonly encountered by aircraft. Upward propagating gravity waves are a frequent cause of upper-level turbulence.

Turbulence is very common in the near vicinity of thunderstorms, including over the top of storms. Diversion of air traffic to avoid thunderstorms is common on all the major routes, but is perhaps worst on the western side of the country, affecting international traffic headed toward Peru and Chile. Thunderstorms in the deep troposphere typical of Colombia are often quite tall, extending to over 50,000 ft.

1.4.5 Volcanic ash

Volcanic ash can be a serious safety issue for aircraft that inadvertently fly through ash plumes. Several volcanoes exist around the region and occasionally affect the airspace over Colombia.

1.4.6 Icing

The accretion of ice of aircraft flying through super-cooled liquid clouds is a significant hazard in some parts of the world. While such icing does occasionally occur in convective clouds in Colombia, most of the people interviewed do not consider it to be a significant problem.

2 Summary of tasks and activities undertaken

The contract language for the current work states the task as follows: "Working with the UAEAC, the Consultant will review the existing aeronautical meteorology system in Colombia to determine the condition and state-of-the-art of the system." This effort has been conducted according to the following stages.

(1) The initial step involved the assessment of the existing Colombian Aeronautical Meteorology System through a review of relevant background materials supplied by UAEAC. These materials were studied in advance of the main site visit by the EarthSat technical team.
(2) Following the examination of background materials, the contractor sent a group of technical experts to Colombia to (a) hold direct meetings with UAEAC staff, (b) to conduct site visits, and in so-doing to (c) become acquainted with the current infrastructure and organization of the Colombian Aeronautical Meteorological System.
(3) In accordance with ICAO, WMO, and FAA planning guidance and documents for the development of international aeronautical meteorological systems, equipment, and information systems the EarthSat team analyzed the strengths and deficiencies of the existing Colombian Aeronautical Meteorology System. The review included an examination of services provided, facilities and instrumentation, supporting infrastructure and maintenance, and human resource issues such as staffing levels, education, and training.
(4) The final step under this task was the preparation and delivery of the current working paper discussing the strengths and deficiencies of the existing Colombian Aeronautical Meteorology System.

2.1 Review of materials supplied by AeroCivil

Our assessment of the Colombian Aeronautical Meteorology System began with an initial review of background materials provided to us by UAEAC. This material included electronic versions of relevant ICAO documents, summaries of existing Colombian meteorological equipment, and responses to specific questions from EarthSat.

The background materials were quite thorough and gave us a good foundation for our fact-finding trips to Colombia.

2.2 Data gathering trips to Colombia

The EarthSat team arrived in Bogotá, Sunday, 28 March 2004, for the primary fact on-site investigation and airport visits, departing on Saturday, 3 April 2004. A second trip was made from 16 May to 21 May 2004 to visit three additional airports.

2.2.1 Meetings with AeroCivil

Our initial meeting with UAEAC staff was held on Monday morning, 29 March. EarthSat team members present for the meeting included Ron Price, Jason Nelsen, Jim Henderson, Brant Foote, David Johnson, Bill Myers, and William Parias. The senior UAEAC staff attending the meeting included the Secretariio Sistemas Operacioncales of Aerocivil, Engineers Pedro Ramon Emiliani, and Cr Victor Plata Cáceres, Director de Servicios a la Navegación Aérea. Other UAEAC staff included Dr. Oscar Bermudez Garcia, Engineers Jose Arturo Garcia Torres, Jose Alfredo Bermudez Salazar, Nibia Lucia Morales Galindo, and Olga Beatriz Martinez Marino.

The meeting included extensive discussion of our visit's goals and priorities, leading to a mutually agreed schedule and agenda. In particular, we developed a detailed list of airports to be visited, airlines to be visited, and key government agencies to be visited. Other important discussions reviewed the UAEAC/IDEAM organizational structures, Colombian weather hazards, observing systems and equipment, communication, maintenance, meteorological staff, and training. We also reviewed the results of a recent consultants' report by Innovative Solutions International (ISI), discussing UAEAC's AIS, COM, and NAV programs.

Monday afternoon we toured the OPMET facility at Bogotá's El Dorado Airport.

During the week we followed up with additional discussions with UAEAC staff through smaller working group discussions, as could be worked out within the week's agenda and travel schedules. On Friday afternoon we finished up with an EarthSat presentation discussing our preliminary impressions and initial assessment of the state of the Colombian aeronautical meteorology system.

2.2.2 Meetings with other government agencies and meteorological groups

Meeting	EarthSat participants
Tuesday, 30 March	
• UAEAC Air Traffic Controllers	Ron Price, Brant Foote, Jim Henderson
• Colombian Air Force (FAC)	Ron Price, Brant Foote, Jim Henderson,
• National University of Colombia	Brant Foote, Jim Henderson
Wednesday, 31 March	
• IDEAM: Engineers Maximiliano Henriques (Subdirector de Meteorología), Francisco Hidalgo (Jefe Programa de Meteorología), and Meteorologist Maria Teresa Martinez	David Johnson, Jim Henderson, Jason Nelsen, William Parias, Bill Myers

2.2.3 *Visits to airports*

Monday, 29 March	
• El Dorado (Bogotá)	Entire EarthSat Team
Tuesday 30 March	
• El Dorado (Bogotá)	Brant Foote, Ron Price, Jim Henderson
• Rionegro	David Johnson, William Parias
• Medellín	David Johnson, William Parias
• Pasto	Bill Myers, Jason Nelsen
Wednesday, 31 March	
• Guaymaral	Jim Henderson, Jason Nelsen
• Quibdó	David Johnson, William Parias
• Cartagena	Brant Foote, Ron Price
• Barranquilla	Brant Foote, Ron Price
Thursday, 1 April	
• Villavicencio	William Parias
• Cali	Brant Foote, Jason Nelsen
• Cúcuta	Bill Myers, Ron Price
• Bucaramanga	Bill Myers, Ron Price
Monday, 17 May	
• Leticia	Brant Foote, William Parias,
Thursday, 20 May	
• San Andrés	Brant Foote
• Providencia	Brant Foote

2.2.4 *Meetings with airlines*

Tuesday, 30 March	
• AeroRepública	Ron Price, Brant Foote, Jim Henderson
Thursday, 1 April	
• Aires	David Johnson
• Satena	David Johnson
• Avianca	David Johnson
Friday, 2 April	
• LAS	Jason Nelsen, William Parias

2.2.5 *Meeting with airline pilots association*

Friday, 2 April	
• Asociación Colombiana de Aviadores Civiles, Capt. Mauricio Leyva Tovar, Director of Safety	Entire EarthSat Team

2.3 Follow-up discussions and additional data gathering

Following our return to the US, EarthSat team members held extensive follow up discussions with UAEAC staff to clarify information we had received during our Colombia visit and to obtain additional information.

EarthSat team members also held discussions or requested supporting information from a large number national and international organizations and commercial companies. These contacts included:

International Agencies

- World Meteorological Organization, Applications Programme Department, Genève, Suisse
- International Civil Aviation Organization (ICAO), Meteorology Section, Air Navigation Bureau, Montreal, Canada
- ICAO, Technical Co-operation Bureau, Montreal, Canada
- ICAO, South American Region, Lima, Peru

US Federal Agencies

- Aviation Weather Center, NOAA, Kansas City, Kansas.
- Telecommunication Operations Center, NOAA, Washington D.C.
- Volcanic Ash Advisory Center (VAAC), Washington D.C.
- National Climate Data Center, Washington D.C.

Airlines

- Federal Express (Global Operations Control)
- Continental Airlines (Dispatch)
- American Airlines
- United Airlines (Dispatch and Operations)
- Weathernews Americas (contract weather provider for American Airline)
- Delta (Dispatch)

Commercial Companies

• Vaisala, USA	Meteorological Systems
• All Weather Inc.	Meteorological Systems (AWOS)
• Sutron Corporation	Meteorological Systems (AWOS)
• Apcytel (Colombia)	MET Systems Support
• Sippican, Inc.	Upper Air Sounding Systems
• Global Science & Technology, Inc. (GST)	WAFS & GVAR Satellite Systems
• SeaSpace Corporation	GVAR Satellite Systems

3 Operational requirements for aeronautical meteorology

In 1944 an international civil aviation conference of 52 nations meeting in Chicago approved a "Convention on International Civil Aviation" (also known as the *Chicago Convention*) and set up a provisional body that in 1947 became the International Civil Aviation Organization (ICAO). Later that same year, ICAO became a specialized agency of the United Nations. In 1948 ICAO adopted standards and recommended practices relating to meteorology as Annex 3 to the Convention. UAEAC is the designated Colombian meteorological authority for aeronautical meteorology and is the national representative to ICAO. The current version of Annex 3 is titled "Meteorological Service for International Air Navigation" (Fourteenth Edition, July, 2001) and is functionally equivalent to WMO Document No 49, Volume 2. In May, 2002, UAEAC and IDEAM signed an Inter-Administrative Agreement, reaffirmed as a priority the modernization of aeronautical meteorological services for Colombia (paraphrased into English) "to ensure the development of a continuous, reliable, convenient, quality, and safe aeronautical meteorological service in the national territory, that allows for air traffic system improvements, as well as guarantees the logical use of resources through execution of a planned investment program, the strengths of each institution (IDEAM and AeroCivil) will be joined to avoid duplication of efforts, means and resources."

ICAO Annex 3 provides standards and recommendations for the provision of aeronautical meteorological services. This annex provides provisions that establish the aeronautical authority of each country to be responsible for aeronautical meteorological services. Annex 3 also recommends how to provide these services.

ICAO Annex 15 requires the establishment of Aeronautical Information Services. The Republic of Colombia has established the Aeronautical Information Publication (AIP) web site which describes the aeronautical meteorological services provided by the Country. The development of a modernized aeronautical meteorological service, however, also requires implementation of the new methods and technologies proposed by the World Meteorological Organization in conjunction with ICAO standards and nation state agreements.

Over the last decade or two there has been strong and organized input from the aviation community regarding the type of meteorological information that is considered necessary to support decisions made by a wide range of end-users including air traffic controllers, traffic managers, pilots (both pre-flight and in-flight phases), dispatchers, and airport operators. In many cases these "user needs" extend beyond ICAO standards.

3.1 ICAO standards and recommended practices

As an ICAO contracting state, Colombia has agreed to establish national regulations and practices that are consistent with Annex 3 and are required to notify ICAO of any differences between their procedures and those specified under Annex 3. Colombia has not filed any notices of differences between their regulations and procedures and those of Annex 3, giving an implied acceptance of these standards and procedures.

Chapters 2 and 3 of Annex 3 provide an overview of the ICAO MET standards and discuss the responsibilities of national aeronautical meteorological services; Chapter 4 discusses meteorological observations and reports; Chapters 6 and 7 review forecasts and warnings. A concise summary of many of the ICAO standards and recommended practices for aeronautical meteorological services is given in Table 3.1 below.

3.1.1 Meteorological Offices

UAEAC is responsible for providing meteorological offices which are adequate for the provision of the meteorological service required to satisfy the operational needs for designated airdromes. Section 3.4 of Annex 3 describes the functions necessary to meet the needs of flight operations at an aerodrome. Each meteorological office shall carry out all or some of the following functions:

a) Prepare and/or obtain forecasts and other relevant information for flights with which it is concerned (In Colombia, forecasts are provided by the Bogotá Meteorological Watch Office, but only for seven airports).
b) Prepare and/or obtain forecasts of local meteorological conditions
c) Maintain a continuous survey of meteorological conditions over the aerodromes for which it is designated to prepare forecasts
d) Provide briefing, consultation, and flight documentation to flight crew members and/or other flight operations personnel
e) Supply other meteorological information to aeronautical users
f) Display the available meteorological information
g) Exchange meteorological information with other meteorological offices
h) Supply information received on pre-eruption volcanic activity, a volcanic eruption or volcanic ash cloud, to its associated air traffic services unit, aeronautical information service unit and meteorological watch office as agreed between the meteorological, aeronautical information service and ATS authorities concerned.

The above functions are detailed by the Regional Air Navigation (RAN) meetings and published in two volumes: a regional basic air navigation plan (ANP), and a facilities and services implementation document (FASID). These agreements may also be expanded by supplementary agreements between the meteorological authority and the operator concerned. The aerodromes for which meteorological observations and landing forecasts are required are specified in the Basic ANP and FASID. For aerodromes without meteorological offices the meteorological authority designates one or more meteorological offices to supply meteorological information as required and establishes a means by which such information can be supplied to the aerodromes concerned. Details of the CAR/SAM Basic ANP and FASID documents for the CAR/SAM region that specify the international meteorological responsibilities of the Republic of Colombia are discussed in Section 3.2.

Table 3.1 ICAO (and Colombia) MET Requirements

General
"Users" defined (*Annex 3, Para. 2.1.2*)
User needs referenced (*Annex 3, Para. 2.2.1*)

Met Watch Offices (MWO)
Responsibilities include (Annex 3, Para. 3.5):
- Issue TAFs (responsibility transferred from MOs)
- Issue SIGMETs (including volcanic ash)
- Issue AIREPs (also referred to as PIREPs)

For AIREP references, see: CAR/SAM Basic ANP, 6.18 & 6.19, as well as Annex 3, Para. 5.9.2-5.9.4

AIRMETs not required in CAR/SAM (*CAR/SAM Basic ANP, 6.32*)

Aerodrome Met Offices
Responsibilities include (Annex 3, Para. 3.4):
- Met observations (collect, display & disseminate)
- Pilot briefings and flight documentation
- Monitor volcanic eruptions and airborne ash
- Forecasts (responsibility delegated on to Bogotá MWO)

24-hour MET service desired (*CAR/SAM Basic ANP, 6.7 & 6.15*)

If aerodrome hours are limited, routine MET reports and forecasts should be available to support flight operations as soon as airport opens (*CAR/SAM Basic ANP, 6.8*)

Airport Surface Observations (METAR & SPECI)
Monitor weather conditions, report hourly (*Annex 3, 4.2.1*)

International dissemination of METARs & SPECI are required for airports designated in the CAR/SAM Basic ANP and FASID.

Hourly observations should include:
- Temperature* & dew point*
- Pressure (QNH* and QFE)
- Wind speed and direction
- Present weather
- Clouds (amount, type, height of base)
- Visibility
- RVR (see following discussion)

**parameters required in all reports (CAR/SAM Basic ANP, 6.16)*

Instruments should be located to provide observations over the runway, approach, and departure areas (*Annex 3, 4.1.6*)

Wind measurements are made at a height of 6-10 m (*4.5.2*) When multiple wind sensors are installed, they should be monitored by automatic equipment. (*4.5.8*)

RVR measurements are discussed in ICAO Doc 9328, "Manual of RVR Observing and Reporting Practices." RVR observations are required for CAT II ILS runways and recommended for CAT I ILS approach runways and non-precision illuminated runways used for take-offs. (*Annex 3, 4.7*)

NOTE: All Annex 3 references are based on the 14th Edition (2001)

Terminal Area Forecasts (TAF) (*Annex 3, Section 6.2*)
Forecasts will be issued at 6 hour intervals with a period of validity of 24 hours (*CAR/SAM Basic ANP, 6.20*)

TAFs will be issued for international airports designated in the CAR/SAM Basic ANP and FASID documents – currently 7 airports.

Automatic Terminal Information Service (ATIS)
ATIS weather broadcasts are required at designated international airports (*CAR/SAM Basic ANP, Table AOP-1*)

Precision Approach and ILS
CAT II ILS systems require integrated automatic systems for surface wind, RVR and cloud height (*Annex 3, Para. 4.1.8*)

Integrated automatic systems for wind, RVR and cloud height are also recommended for CAT I ILS (*Annex 3, Para. 4.1.9*)

Briefings and Services
Meteorological information must be supplied to operators and flight crew members in the form of written materials, briefings, or automated self-briefing facilities (*Annex 3, Chapter 9*)

Pre-flight briefings should include information for take-off, en-route, destination, and alternate airdromes in the form of METARs, TAFs, SIGMETs, and other available MET information.

Standard international flight documentation packages are based on materials distributed via WAFS, augmented by local materials.

Automated pre-flight briefings should include all information specified in Annex 3, Para. 9.1-9.8 and Annex 15, Para. 8.1-8.2

Calibration and Maintenance
Quality management of MET products (*Annex 3, Para 2.2.2 & 2.2.4 and 4.4b*)
Verify dissemination of data and products (*Annex 3, Para. 2.2.5*)

Climatological Information
Aerodrome climatological tables and summaries are required for planning flight operations (*Annex 3, Chapter 8*)

At least a 5 year data record is recommended. Additional continuing data collections should be encouraged, but are not required (*Annex 3, Para. 8.1.2*)

Sample climatological summaries are given by the WMO (*WMO, Pub. 49, Technical Regulations, Volume II, C.3.2*)

Climatological data required for other aerodrome planning purposes are described in Annex 14, Volume 1, Para. 3.1.3

Upper-air soundings (radiosondes)
Soundings are a WMO World Weather Watch commitment, but are also essential for aviation weather. (*WMO, 2004*)

3.1.2 Meteorological Watch Offices (MWO)

Having accepted the responsibility for providing air traffic services within its two flight information regions (FIR) or control areas, the Republic of Colombia is obligated to maintain one or more meteorological watch offices, or to arrange for another contracting state to do so. The meteorological watch office shall:

a) Maintain watch over meteorological conditions affecting flight operations within its area of responsibility
b) Prepare SIGMET and other information relating to its area of responsibility
c) Supply SIGMET information and, as required, other meteorological information to associated air traffic services units
d) Disseminate SIGMET information
e) When required by the Regional Air Navigation Agreement,
    1) Prepare AIRMET information related to its area of responsibility
    2) Supply AIRMET information to associated air traffic services units
    3) Disseminate AIRMET information;
f) Supply information received on pre-eruption volcanic activity, a volcanic eruption and volcanic ash cloud for which a SIGMET has not already been issued, to its associated ACC/FIC, as agreed between the meteorological and ATS authorities concerned, and to its associated VAAC as determined by RAN
g) Supply information received concerning the accidental release of radioactive material into the atmosphere

SIGMETs are issued for a variety of en-route weather hazards including thunderstorms, tropical cyclones, turbulence, in-flight icing, and volcanic ash. AIRMETs are not required by CAR/SAM (reference: Basic ANP, Part VI, paragraph 32).

3.1.3 Volcanic ash advisory center (VAAC)

Under the terms of the International Airways Volcano Watch, the Washington D.C. VAAC is responsible to provide Colombia's designated MWO with specific ash advisories in the event of a volcanic eruption that has the potential to impact Colombian air space. Because of the need for timely collaboration between the member states and the regional VAAC, Colombia has the responsibility to be the national liaison with Colombia's designated volcano observatories and to notify the VAAC of potential eruptions before they occur. After an eruption which has the potential to eject volcanic ash to elevations where they could impact air traffic, the designated MWO should immediately issue a SIGMET announcing the eruption and contact the VAAC to notify them of the eruption. After receipt of a formal Volcanic Ash Advisory from the VAAC, the MWO should issue a revised SIGMET in accordance with the VAAC's advisory.

Specific procedures and responsibilities with respect to volcanic eruptions are detailed in the ICAO "Handbook on the International Airways Volcano Watch: Operational

Procedures and Contact List." The most recent version of this handbook (Second Edition, 2004) is available online at:

http://www.icao.int/icaonet/dcs/9766_2_en.pdf

3.2 Regional regulations and agreements

While Section 3.1 above describes the general ICAO and WMO recommended International Standards and Practices, the many specific requirements for the provision of aeronautical weather services are governed by regional agreements within the Caribbean/South American (CAR/SAM) region such as Document 8733 (Version 14) which details the Regional Basic Air Navigation Plan (ANP) and the Facilities and Services Implementation Document (FASID).

3.2.1 CAR/SAM Basic ANP and FASID

These documents list specific commitments by the Republic of Columbia to provide aeronautical weather services from specific meteorological offices and a meteorological watch office. Strictly speaking, these commitments are only relevant to designated international airports, but the services provided will usually be needed for domestic flights as well. In Part VI, "Meteorology," the Basic ANP document effectively defines a minimum standard for all CAR/SAM for MET facilities and service.

In an appendix to Part III, the Basic ANP document identifies eight international airports for Colombia:

Barranquilla/Ernesto Cortissoz
Cali/Alfonso Bonilla Aragón
Cartagena/Rafael Núñez
Cúcuta/Camilo Daza *
Leticia/Alfredo Vasquez Cobo
Rionegro/José Maria Córdoba
San Andrés I./Sesquicentenario
Santa Fe De Bogotá/ El Dorado

FASID Table MET 1A specifies that each of these airports will be provided TAFs and Table MET 2A specifies that (except for Cúcuta) these airports will disseminate TAFs and METARs to a specified list of international airports. With the exception of Leticia and Cúcuta, these airports are identified (FASID, Table MET 1A and Table AIS 2) as being used regularly for international scheduled air transport. Leticia and Cúcuta are identified as being used regularly for non-scheduled international air transport and used as international alternate airports.

* Note that METARs and TAFs are not disseminated for Cúcuta.

These airports, of course, also have Aeronautical Information Service Units (FASID, Table AIS 2) and provide weather briefing, consultation, and flight documentation services to flight crew members or other operations personnel.

FASID Table MET 1B identifies a single meteorological watch office (MWO) serving all of Colombia: Santa Fe De Bogotá/ El Dorado.

This MWO is responsible for providing a MET watch over the Bogotá FIR/UIR/SRR and the Barranquilla FIR (below FL200). This MWO is also responsible for issuing SIGMETs. The MWO receives tropical cyclone advisories from the Tropical Cyclone Advisory Center in Miami and volcanic ash advisories from the Volcanic Ash Advisory Center in Washington. Volcanic Ash Advisories are also sent to the Barranquilla CAA.

Airport-by-airport details of the services provided at Colombian airports are available on the AeroCivil web site as part of the Aeronautical Information Publication (AIP) specified in ICAO Annex 15. The web resource provides detailed information for domestic as well as international aerodromes.

3.2.2 CAR/SAM Regional Plan for CNS/ATM Systems

The CAR/SAM Regional Plan for the Implementation of the CNS/ATM Systems (ICAO, 1999) discusses the ways that meteorological services in the CAR/SAM region will have to change to support the evolutionary transition to the new generation of ATM systems. In particular, this document reviews the need for improved meteorological information and more efficient communication systems to evolve from a national-based system to a more flexible global system.

In the present system, meteorological information has frequently been limited to local or national distribution so as not to overload the international AFTN (see Section 4.6), with weather forecasts being produced locally to widely differing standards. The new system that is evolving provides for the centralized production of a basic set of standard meteorological products, both global and regional, at two World Area Forecast Centers (WAFCs) that are then widely disseminated to users in each geographical region. This centralized production of products is complimented by a decentralized distribution of the basic meteorological observations and locally produced warnings to international centers such as the WAFCs, and simultaneously to a wide spectrum of individual users.

So far, the most significant meteorological accomplishments of the CNS/ATM transition have been the expansion and improvements in the WAFS system, providing VSAT-based distribution of the WAFC products to Colombia and other South and Central American nations, and a parallel WAFS satellite uplink capability for transmitting weather observations and locally-produced products to the Washington WAFC.

The global ATM system will require access to global meteorological information on a far shorter time scale than has been customary in the past. This will require further enhancements in systems for the exchange of OPMET messages with faster communication links and automated systems for observation, data entry, and transmission.

Future enhancements to meteorological systems will provide wider access, both in-country and internationally, to more observations. Operationally this will require increased use of automated systems. While humans will usually still be involved in the data collection, their role will move to being more of a sophisticated user monitoring the observations for data quality before they are distributed and not having to make manual data entries or retype products for multiple transmissions. At the same time, the regional implementation plan calls for the development of automated AIS/MET pre-flight briefing facilities and products that will provide an enhanced situational awareness of Colombian and Regional weather systems and hazards. These changes will have a major impact on individual job responsibilities and require additional a significant commitment to advanced training and further education of meteorological staff.

The transition to the new CNS/ATM systems will also be accompanied by new observational systems and capabilities. These new systems will frequently be based on remote sensing capabilities including satellite observations, meteorological radars, lidars, and lightning detection systems and will be used in conjunction with mesoscale numerical models and local SIGMETs and AIREPs to produce the enhanced situational awareness that is needed for effective pre-flight briefings, air traffic control, and dispatch operations.

In recent years it has become evident that valuable meteorological data can be obtained by aircraft fitted with appropriate software packages. To date the predominant sources of automated aviation data have been from ASDARs (Aircraft to Satellite Data Relay), and more recently ACARS (Aircraft Communication Addressing and Reporting System) equipped aircraft. ACARS systems, route data back via general purpose information processing and transmitting systems now fitted to many commercial aircraft. Such systems offer the potential for a vast increase in the provision of aircraft observations of wind and temperature.

The various systems (e.g., ASDARS and ACARS) are collectively named AMDAR (Aircraft Meteorological Data Reporting) systems and are making an increasingly important contribution to the observational data base of the World Weather Watch (WWW) of the World Meteorological Organization. In particular, data obtained during takeoffs and landings provides high resolution virtual soundings that augment a country's daily radiosonde launches and permit the tracking of stable layers and inversions. These data sets are automatically down-linked to receiving stations where they can be incorporated into local, national, and international OPMET databases. In the future, AMDAR data may largely supersede manual air reporting (AIREPs).

The hallmark of the new meteorological systems will be faster response times to time-critical hazards such as pilot reports of turbulence or volcanic eruptions.

With the ability to distribute more observations and local products and warnings, there will be a need to update and expand the regional FASID agreements to reflect these new capabilities and new requirements.

3.3 World Meteorological Organization responsibilities

In addition to Colombia's ICAO obligations and responsibilities for exchange and dissemination of meteorological information, Colombia is also a participant in the World Meteorological Organization's World Weather Watch Program and has reporting responsibilities under that program. IDEAM is the designated national representative to the WMO and is responsible for carrying out the WWW observations and reports.

These observations and reports, however, also impact Colombia's aeronautical meteorology program since the bulk of the Colombia's synoptic reporting stations under the World Weather Watch are airports. In addition, Colombia's upper air soundings (which are essential for forecasting convection and the issuance of SIGMETs) are collected and distributed under the WWW through the WMO's Global Telecommunication System (GTS).

3.3.1 The Global Observing System of the World Weather Watch

WMO "Publication No. 9, Weather Reporting, Volume A - Observing Stations" presents a full listing of the international synoptic and upper-air reporting stations with a detailed summary of their expected reports. Table 3.2 summarizes the Colombian stations reported in Publication No. 9, Volume A.

The material extracted from Volume A is summarized in the block at the right. For each station, the table indicates whether upper air soundings are collected (radiosonde column), and if so at what time the sounding is collected. The expected report from these stations is the synoptic report, or SYNOP, that is usually taken every 3 hours. The SYNOP columns indicate the times for which each station is expected to report a synoptic observation. In many cases the stations are airports which issue hourly METARs (indicated by the check mark in the AIRPORT and METAR columns). In this case the METAR can either be submitted in place of the SYNOP, or may be reported in addition to the SYNOP. If METARs are reported, the METAR Hours column indicated the hours for which the METARs are reported. In addition to these routine observations, there are additional reports including CLIMAT (C) and CLIMAT (T) reports, which are monthly climatic summaries of the service observation and upper air soundings, respectively. Addition special reports include reports of soil temperature, evaporation, solar radiation, and duration of sunshine.

Table 3.2
WMO Global Observing System for the World Weather Watch

Colombian Reporting Stations | **WMO Publication No. 9, Volume A – Observing Stations**

STATION	ATC Controlled Airport	MET OPS	AIRPORT	RADIOSONDE 00Z	RADIOSONDE 12Z	RADIOSONDE NOTE	METAR	METAR Hours UTC	SYNOP 0	SYNOP 3	SYNOP 6	SYNOP 9	SYNOP 12	SYNOP 15	SYNOP 18	SYNOP 21	AIRPORT	METAR	SPECI	CLIMAT (T)	CLIMAT (C)	EVAP	AGRIMET	SOILTEMP	SOLRA	SUNDUR
MEDELLIN	X	X	X				X	H10-24	-	-	-	-	X	X	X	X	X	X	X							
RIONEGRO	X	X	X				X	H00-24	X	X	X	X	X	X	X	X	X	X	X		X					
QUIBDO	X	X	X				X	H10-24	-	-	-	-	X	X	X	X	X	X	X		X	X				X
MONTERIA	X	X	X				X	H11-23	-	-	-	-	X	X	X	X	X	X	X							
CAREPA (Los cedros) APARTADO	X	X	X				X	H11-23	-	-	-	-	X	X	X	X	X	X	X		X					X
MANIZALES	X	X	X				X	H11-23	-	-	-	-	X	X	X	X	X	X	X							
OTU			X						-	-	-	-	-	-	-	-										
CONDOTO								H12-19	-	-	-	-	X	X	X	-										
TURBO			X				X		-	-	-	-	-	-	-	-	X	X	X							
CARTAGENA	X	X	X				X	H00-24	X	X	X	X	X	X	X	X	X	X	X		X	X				X
BARRANQUILLA	X	X	X				X	H00-24	X	X	X	X	X	X	X	X	X	X	X		X	X				X
SANTA MARTA	X	X	X				X	H11-05	-1	-	-	-	X	X	X	X	X	X	X		X					X
SAN ANDRES	X	X	X	—	X	WTR	X	H10-03	X	X	-	-	X	X	X	X	X	X	X	X	X	X				X
VALLEDUPAR	X	X	X				X	H11-23	-	-	-	-	X	X	X	X	X	X	X							
COROZAL	X	—	X				X	H11-23	-	-	-	-	X	X	X	X	X	X	X							
PROVIDENCIA, airport & agricultue?	X	X	X					H10-24	X	-	-	-	X	X	X	X		X			X		X			
RIOHACHA	X	X	X	—	X	—	X	H11-23	X	-	-	-	X	X	X	X	X	X	X	X						
MAGANGUE			X				X	H11-23	-	-	-	-	X	X	X	X	X	X	X			X			X	X
EL BANCO			X				X	H12-19	-	-	-	-	X	X	X	-	X	X	X			X				X
BOGOTA D.C.	X	X	X	X	X	WTR	X	H00-24	X	X	X	X	X	X	X	X	X	X	X	X	X	X				X
GIRARDOT	X	X	X				X	H11-23	-	-	-	-	X	X	X	X	X	X	X		X					
IBAGUE	X	X	X				X	H11-23	X	-	-	-	X	X	X	X	X	X	X		X	X				X
NEIVA	X	X	X				X	H10-24	-1	-	-	-	X	X	X	X	X	X	X		X	X				X
PUERTO ASIS	X	X	X				X	H12-19	-	-	-	-	X	X	X	X	X	X	X							
FLORENCIA	X	X	X				X	H11-23	-	-	-	-	X	X	X	X	X	X	X							
SAN VICENTE DEL CAGUAN	X	X	X				X	H12-19	-	-	-	-	X	X	X	-	X	X	X							
LETICIA	X	X	X	—	X	—	X	H10-24	X	-	-	-	X	X	X	X	X	X	X	X	X	X				X
PITALITO			X				X	H12-18	-	-	-	-	X	X	X	-	X	X	X							
CALI	X	X	X				X	H00-24	X	X	X	X	X	X	X	X	X	X	X		X	X			X	X
PEREIRA	X	X	X				X	H10-01	-1	X	-	-	X	X	X	X	X	X	X		X					X
ARMENIA	X	X	X				X	H11-23	-	-	-	-	X	X	X	X	X	X	X							
PASTO	X	X							-	-	-	-	X	X	X	X										
POPAYAN	X	X	X						-	-	-	-	-	-	-	-										
TUMACO	X	X	X				X	H11-23	X	X	X	X	X	X	X	X	X	X	X							
TUMACO									-	-	-	-	-	-	-	-										
IPIALES	X	X	X				X	H11-23	X	-	-	-	X	X	X	X	X	X	X		X	X				X
GUAPI	X	X						H11-17	-	-	-	-	X	X	X	X										
BUENAVENTURA	X	X	X				X	H11-23	-	-	-	-	X	X	X	X	X	X	X		X	X				X
BUCARAMANGA	X	X	X				X	H00-24	X	X	-	-	X	X	X	X	X	X	X		X	X			X	X
CUCUTA	X	X	X				X	H10-24	-1	-	-	-	X	X	X	X	X	X	X		X	X				X
BARRANCABERMEJA	X	X	X				X	H11-24	X	-	-	-	X	X	X	X	X	X	X		X	X				X
ARAUCA	X	X	X				X	H10-24	-	-	-	-	X	X	X	X	X	X	X		X					X
TAME	X	X						H12-19	-	-	-	-	X	X	X	X										
OCANA	X	X	X				X	H12-19	-	-	-	-	X	X	X	-	X	X	X							
VILLAVICENCIO	X	X	X				X	H10-24	-	-	-	-	X	X	X	X	X	X	X		X					X
SAN JOSE DEL GUAVIARE	X	X	X				X	H12-19	-	-	-	-	X	X	X	-	X	X	X							
MITU	X	X	X						-	-	-	-	-	-	-	-										
PUERTO CARRENO	X	X	X				X	H10-24	-	-	-	-	X	X	X	X	X	X	X		X					X
TRINIDAD								(H12-20)	-	-	-	-	X	X	X	-										
LOS GAVIOTAS		X		—	X	WT		(H10-24)	-	-	-	-	X	X	X	X				X	X	X		X		
PUERTO LEGUIZAMO									-	-	-	-	-	-	-	-										

For reference, the left hand block adds information about the reporting stations, including identification of which stations are located at controlled airports and conduct meteorological observations (see also Table 4.1).

Even though the online versions of the Publication No 9, Volume A summaries are updated annually, it is not clear how many of the listed stations actually submit their designated reports. In a few cases, indicated by shading in Table 3.2, stations are reported as being "out of service" while still being maintained in the station list (in the WMO jargon they are listed as: "station without observing program").

3.3.2 The Regional Basic Synoptic and Climate Networks

In addition to the Table 3.2 observing stations that are included under the all encompassing World Weather Watch Global Observing System, each WMO Regional Association designates some stations for inclusion in a Regional Basic Synoptic Network (RBSN). The RBSN is intended to meet the requirements of both the regional states and the World Weather Watch, and represents a more realistic list of expected reporting stations. Similarly, the Regional Associations define a Regional Basic Climatological Network (RBCN) necessary to provide a good representation of climate on the regional scale, in addition to global scale. Stations included in the RBSN and the RBCN are listed on the WMO Website. Table 3.3 indicates which of the stations listed in Table 3.2 are designated for inclusion in the RBSN or the RBCN.

The RBCN stations listed under the CLIMAT column in Table 3.3 provide monthly climatological summaries of surface observations. Stations listed under CLIMAT-TEMP provide monthly climatological summaries of their upper-air sounding. Stations for which there is a long history of reliable reports are further designated as components of the Global Climate Observing System (GCOS) Surface Network (GSN) or the GCOS Upper Air Network (GUAN). These stations are considered to be the most reliable and most dependable for global climate studies (WMO, 2002). In Colombia, five of the six listed GSN stations regularly report climate summaries, as verified by their availability at the (US) National Climate Data Center. The five GSN stations are San Andrés, Bogotá, Cali, Pasto, and Los Gaviotas. Of Colombia's upper-air stations, only Bogotá is included in the GUAN.

Table 3.3
WMO Regional Basic Synoptic and Climate Networks

Colombian Reporting Stations				RBSN List		RBCN List			
STATION	ATC Controlled Airport	MET OPS	AIRPORT	Regional Basic Synoptic Network Stations		Regional Basic Climatological Network Stations			
				Surface	Radiosonde	CLIMAT	CLIMAT TEMP	GSN	GUAN
MEDELLIN	X	X	X						
RIONEGRO	X	X	X	X		X			
QUIBDO	X	X	X	X		X			
MONTERIA	X	X	X	X					
CAREPA (Los cedros) APARTADO	X	X	X	X		X			
MANIZALES	X	X	X						
OTU			X	X					
CONDOTO									
TURBO			X						
CARTAGENA	X	X	X	X		X			
BARRANQUILLA	X	X	X	X		X			
SANTA MARTA	X	X	X	X		X			
SAN ANDRES	X	X	X	X	X	X	X	X	
VALLEDUPAR	X	X	X	X					
COROZAL	X	—	X						
PROVIDENCIA	X	X	X	X		X			
RIOHACHA	X	X	X	X	X	X	X		
MAGANGUE			X						
EL BANCO			X						
BOGOTA D.C.	X	X	X	X	X	X	X	X	X
GIRARDOT	X	X	X						
IBAGUE	X	X	X	X		X			
NEIVA	X	X	X	X		X			
PUERTO ASIS	X	X	X	X					
FLORENCIA	X	X	X						
SAN VICENTE DEL CAGUAN	X	X	X						
LETICIA	X	X	X	X	X	X	X		
PITALITO			X						
CALI	X	X	X	X		X		X	
PEREIRA	X	X	X	X		X			
ARMENIA	X	X	X			X			
PASTO	X	X		X		X		X	
POPAYAN	X	X	X	X					
TUMACO	X	X	X						
TUMACO				X					
IPIALES	X	X	X			X			
GUAPI	X	X							
BUENAVENTURA	X	X	X	X					
BUCARAMANGA	X	X	X	X		X			
CUCUTA	X	X	X						
BARRANCABERMEJA	X	X	X			X			
ARAUCA	X	X	X	X					
TAME	X	X							
OCANA	X	X	X						
VILLAVICENCIO	X	X	X	X		X			
SAN JOSE DEL GUAVIARE	X	X	X	X					
MITU	X	X	X	X					
PUERTO CARRENO	X	X	X	X		X			
TRINIDAD									
LOS GAVIOTAS		X		X		X	X	X	
PUERTO LEGUIZAMO									
CARMEN BOLIVAR						X		X	

3.3.3 The World Weather Information Service

Colombia, through IDEAM, is also participating in a WMO pilot project which maintains a centralized web site for official weather forecasts and climate data for participating member states, the World Weather Information Service (http://worldweather.org/)

At present, the WWIS provides forecasts and climate data for thirty Colombian cities.

Table 3.4
Colombian Cities Included in the World Weather Information Service

Apartado	Florencia	Providencia
Arauca	Ibaque	Puerto Carreno
Armenia	Leticia	Quibdó
Barrancabermeja	Manizales	Riohacha
Barranquilla	Medellín	San Andrés, Island
Bogotá	Monteria	Santa Marta
Bucaramanga	Neiva	Tumaco
Cali	Pasto	Tunja
Cartagena	Pereira	Valledupar
Cúcuta	Popayan	Villavicencio

3.4 Recommendations and requirements from the international aviation end-user community

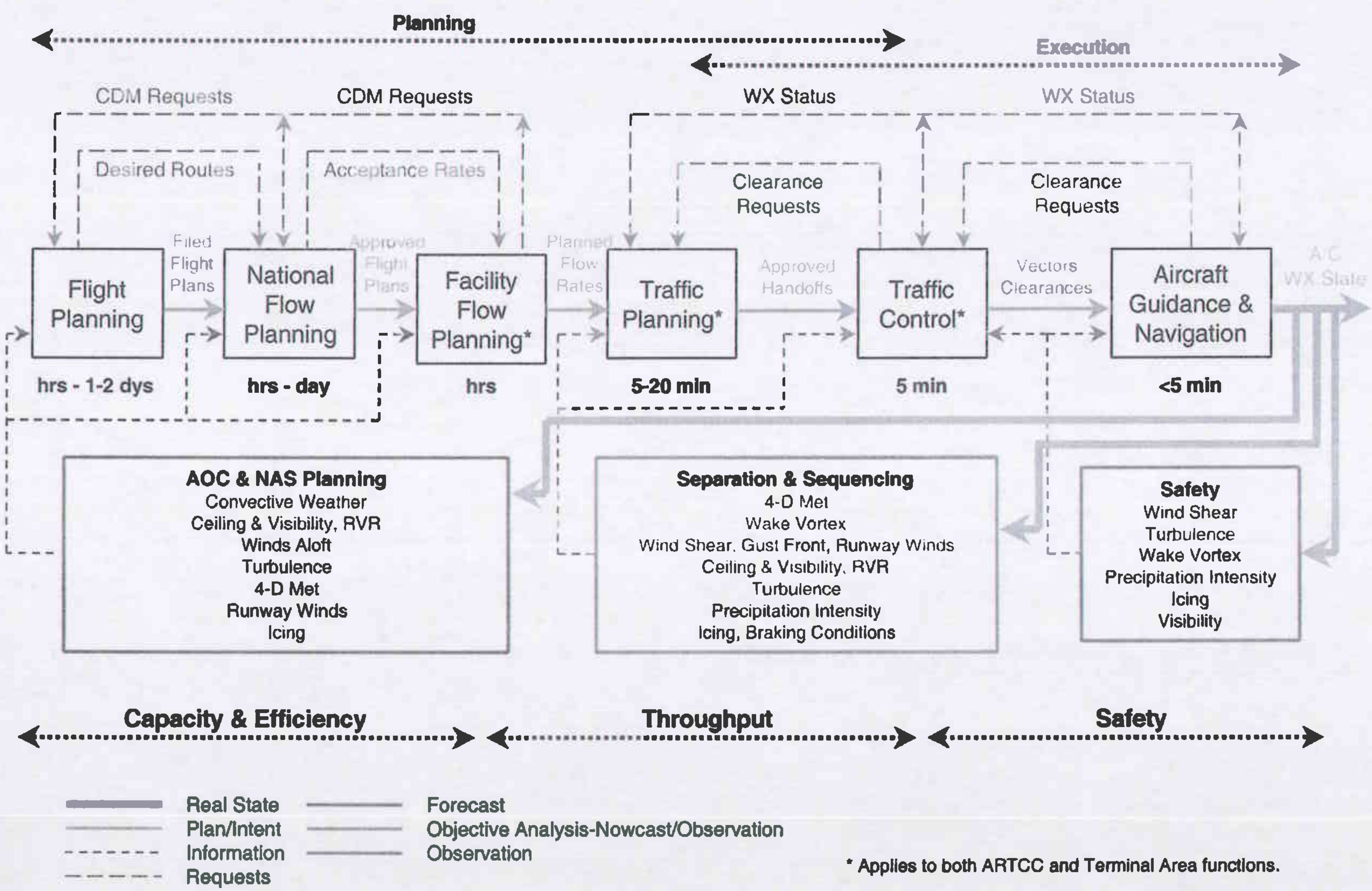
As noted in Sec. 1.4, there are a variety of weather phenomena that adversely affect aviation operations. Some of these are clear safety issues, some relate to efficiency of operations, and some affect the capacity of the airspace system. In addition to the national and international requirements that have been established, and which form the basis for obligations for individual countries, there are a large number of studies that address other important ways to mitigate the various weather hazards. While these recommendations have not yet been adopted as absolute requirements, they should be regarded as highly desirable augmentations to official civil aviation requirements. They establish the important planning directions toward which aviation weather systems should be headed. Thus, it is important for this study to review the recommendations that the aviation end users believe should become requirements for the future.

According to a report for the National Research Council titled *Aviation Weather Services: A Call for Federal Leadership and Action,* addressing aviation weather problems will require that aviation authorities take on the responsibility of separation of "aircraft from hazardous weather," in addition to separating "aircraft from aircraft." This means that weather services must become an important part of air traffic responsibilities. The civil aviation authority should develop procedures and weather products to improve the ability of pilots and controllers to ensure that aircraft avoid hazardous weather.

In a 1998 report titled *Aviation Weather Study Final Report,* prepared by Charles Lindsey at Northwest Research Associates for Boeing Commercial Airplane Group, the argument is made that improved weather information is a critical element for increasing capacity in the airspace system. In Figure 3.1, Mr. Lindsey depicts a functional structure of the ATM system that is based on the concept that system capacity is inextricably linked to separation standards. This model shows how aviation weather information is mapped into the separation function. This paradigm is intended to capture the future requirements for aviation weather. Key findings inherent in the figure include:

- The majority of meteorological information required affects efficiency, capacity, and throughput.
- The Airline Operations Center (AOC) and Air Traffic Management (ATM) planning functions affect system efficiency and helps establish daily capacity.
- The weather information generated in the separation function affects system throughput.
- The safety function relies almost exclusively on observations.

Figure 3.1



* Applies to both ARTCC and Terminal Area functions.

According to the *Final Report of the Commission on the Future of the United States Aerospace Industry, November 2002,* the nation needs a new, highly automated "Interstate Skyway System" that is safe, secure, and efficient, and accommodates the volume and variety of civil and military air transportation that will be demanded by the nation in the coming decades. The Commission saw a powerful opportunity to develop a common advanced technology infrastructure that would form the foundation of this new system and simultaneously enhance civil aviation, homeland security, and national defense. Key technology being developed by a number of Government Agencies and the private sector should be brought together to establish that infrastructure, which includes:

- Secure, high bandwidth digital communication systems replacing today's analog voice radios.
- Precision navigation reducing position errors for all aircraft to within a few meters.
- Precision surveillance systems accurately locating all aircraft, and automatically detecting any deviations from an approved path within seconds.
- High-resolution weather forecasts creating 4-dimensional (space and time) profiles, accurate for up to 6 hours for all atmospheric conditions affecting aviation, including wake vortices.
- Highly accurate digital data bases depicting terrain, obstacle, and airport information no matter what visibility conditions exist.

The Commission concluded that with the notable exception of accurate short-term weather prediction and wake vortex forecasting, many of these basic technologies already exist. The Government has used many of these technologies for years. But the weather forecasting and integration problem must be solved.

Foremost among the issues that must be resolved if reduction of weather-related delays is to be achieved is the improvement of thunderstorm forecasting in the 0 to 6-hour timeframe and the integration of this forecasting information into ATC/ATM automated decision support systems. In a 2003 National Research Council Report titled *Weather Forecasting Accuracy for FAA Traffic Flow Management,* the development of probabilistic forecasting, characterizing the impact of forecast weather on ATM decision making, and integration of probabilistic forecasts directly into the ATM automation decision support systems was viewed as critical.

In 1999, the Office of the Federal Coordinator for Meteorology, in a document titled *National Aviation Weather Initiatives,* identified seven cross-cutting initiatives that were common to meeting almost every user weather need. These initiatives are **Flight Information Services** between the ground and cockpit, **multifunctional color cockpit displays** incorporating the FIS products, implementation of **automated pilot reports,** improved **weather forecasting services,** improved **training,** improved **aviation weather telecommunications capabilities,** and **objective standards** for characterizing weather phenomena.

As early as 1994, the National Research Council's report *Weather for Those Who Fly,* insisted that firm plans must be developed for implementing graphical presentations of aviation weather variables and decision aids tailored for four-dimensional flight planning and management. They should be in formats specific to terminals, aircraft routes, and aircraft type. High priority should be placed on designing and implementing the infrastructure to make such presentations available on the ground to pilots, controllers, and dispatchers; and developing a system for providing appropriate displays in the cockpits of aircraft.

In today's U.S. aviation system, many pilots rely on the Direct User Access Terminal Service (DUATS) (a totally automated service) and Flight Service Stations (FSS) for communication of weather information. In a January, 2004 report from Mitre/CAASD titled *Flight Service Station Survey Report,* it as reported that users have doubts about the trustworthiness of DUATS information and their ability to interpret the information. There is a lack of confidence in DUATS. On the other hand, the users seem to rely on the timeliness and accuracy of the information from the FSS and the interpretation of the FAA Specialist, in other words, they greatly value the human interaction. This important survey highlights the need to find ways of incorporating the best of internet and live briefer technology into a single integrated pilot weather information system.

As discussed in Sec. 1.4 earlier, various weather phenomena such as thunderstorms, reduced visibility, adverse winds, in-flight icing, turbulence, and winter storms affect airports and en-route airspace. A number of different types of operational decision makers are involved in the process of mitigation of the impacts of these phenomena, and require access to weather data presented in clear, concise, easy to understand formats, as well as specific meteorological training in the use, interpretation, and application of the weather information. These include pilots, air traffic controllers, air traffic management specialists, dispatchers, and airport ground personnel. Weather has an impact on numerous types of decisions.

The following matrices (Table 3.5), extracted from *Mission Need Statement for Aviation Weather MNS#339,* were prepared by the U.S. Federal Aviation Administration in June, 2002, and detail the decision makers, the types of decisions made, and the types of weather information they need.

Table 3.5

End Users (Decision-Makers)	Capabilities → Weather Decisions ↓	Access by pilots/aerospace vehicle operators/FSS specialists/dispatchers to weather information prior to departure	Access to weather information by pilots/aerospace vehicle operators/FSS specialists/dispatchers in-flight	Current/nowcast weather information for ground operations	Provide common situational awareness for weather information (flight deck crew and ground personnel)	Provide current/nowcast/ forecast weather information for approach/departure operations	Provide current/nowcast/ forecast weather information for en route, oceanic, and aerospace operations	Provide current/nowcast/ forecast weather information for traffic flow management operations
	Route/Altitude Selection	X			X			
	Deicing Decision	X						
	Taxi/Route Selection (uncontrolled airports)			X				
	Runway Selection (uncontrolled airports)			X				
Pilots (Part 91, 135, 121)	Go/No-Go Decision	X						
	Escape Decision		X		X			
	In-flight Route Change		X		X			
	Hazardous Weather Deviation		X		X			
	Approach Commencement		X		X			
	Landing Decision		X					
	Departure Location/Trajectory Decision	X			X			
	Deicing Decision	X						
	Go/No-Go Launch Decision	X						
	Abort/Destruct Decision		X		X			
Aerospace Vehicle Operators	Escape Decision		X		X			
	In-flight Route Change		X		X			
	Hazardous Weather Deviation		X		X			
	Go/No-Go Reentry Decision		X		X			
	Approach Commencement		X		X			
	Landing Decision		X					
	Metering/Spacing Decision						X	
En Route Controllers	Route/Altitude Selection				X		X	
	Approach /Departure Route Selection				X		X	
	Approach/Departure Clearance				X		X	
Oceanic Controllers	Metering/Spacing Decision						X	
	Route/Altitude Selection				X		X	

Table 3.5 (continued)

End Users (Decision-Makers)	Capabilities → / Weather Decisions ↓	Access by pilots/aerospace vehicle operators/FSS specialists/dispatchers to weather information prior to departure	Access to weather information by pilots/aerospace vehicle operators/FSS specialists/dispatchers in-flight	Current/nowcast weather information for ground operations	Provide common situational awareness for weather information (flight deck crew and ground personnel)	Provide current/nowcast/ forecast weather information for approach/departure operations	Provide current/nowcast/ forecast weather information for en route, oceanic, and aerospace operations	Provide current/nowcast/ forecast weather information for traffic flow management operations
Approach/Departure Controllers	Metering/Spacing Decision					X		
	Route/ Altitude Selection					X		
	Arrival/Departure Route Selection				X	X		
Local Controllers	Metering/Spacing Decision			X	X	X		
	Airport Traffic Pattern Change					X		
	Runway Selection			X		X		
Ground Controllers	Taxi Route Selection			X				
Aerospace Controllers (Space Operations Coordinators)	Metering/Spacing					X	X	
	Route/Altitude Selection				X	X	X	
	Approach /Departure Route Selection				X	X	X	
	Approach/Departure Clearance				X		X	
	Reentry Clearance				X	X	X	
Traffic Managers (NAS, Approach/Departure, Air Route)	Airport Acceptance Rate Determination				X			X
	Ground-Stop/Delay Decision				X			X
	Route Change				X			X
	SWAP Implementation				X			X
	Metering/Spacing Decision				X			X
Flight Service Station Specialists	Route/Altitude Selection	X			X			
	Go/No-Go (VNR)	X						
	Runway Selection			X				
	Hazardous Weather Deviation		X		X			
	Escape Decision		X		X			
Airline Dispatchers	Route/Altitude Selection	X			X			
	Deicing Decision	X			X			
	Go/No-Go Decision	X						
	In-flight Route Change		X		X			
Airport Managers[2]	Airport, Runway, or Taxiway Closure			X	X			
	Cease Refueling Operations			X				
Spaceport Operators[2]	Spaceport, Runway, or Taxiway Closure			X	X			
	Cease Refueling Operations			X				

Table 3.5 (continued)

Decision-Makers →	Pilots (Part 91, 135, 121)										Aerospace Vehicle Operators										En Route Controllers				Oceanic Controllers		Approach/ Departure Controllers			Local Controllers			Ground Controllers	
Decisions → / Information Types ↓	Route/Altitude Selection	Deicing Decision	Taxi/Route Selection (uncontrolled airports)	Runway Selection (uncontrolled airports)	Go/No-Go Decision	Escape Decision	In-flight Route Change	Hazardous Weather Deviation	Approach Commencement	Landing Decision	Departure Location/Trajectory	Deicing Decision	Go/No-Go Launch Decision	Abort/Destruct Decision	Escape Decision	In-flight Route Change	Hazardous Weather Deviation	Go/No-Go Reentry Decision	Approach Commencement	Landing Decision	Metering/Spacing Decision	Route/Altitude Selection	Approach/Departure Route Selection	Approach/Departure Clearance	Metering/Spacing Decision	Route/Altitude Selection	Metering/Spacing Decision	Route/Altitude Selection	Arrival/Departure Route Selection	Metering/Spacing Decision	Airport Traffic Pattern Change	Runway Selection	Taxi Route Selection	Information Includes....
Thunderstorm (Deep Convection)	x		x	x	x	x	x	x	x	x	x		x		x	x	x	x	x	x	x	x	x		x	x	x	x	x	x	x	x	x	Location of precipitation and lightning (in-cloud, cloud-to-ground), hazardous weather information such as hail (including hail size), in-storm turbulence, echo tops, up/downdrafts, tornadoes, mesocyclones. Nowcast of convective initiation and precipita
Stratiform Precipitation Events	x		x	x	x	x	x	x	x	x	x		x		x	x	x	x	x	x	x	x	x		x	x	x	x	x		x	x	x	Cold season synoptic storm information. Widespread low-level visibility associated with advection fog, orographic stratus, valley fog.
Low-level Windshear			x	x	x	x		x	x	x			x	x			x		x	x			x				x		x	x	x	x	x	Location and nowcast of microburst and windshear; gust front and windshift line location.
In-flight Icing	x				x	x	x	x		x	x		x	x	x	x	x	x		x	x	x	x		x	x	x	x	x	x				Location, forecast and nowcast, including freezing level.
Surface Level Icing		x	x	x	x					x		x	x							x							x					x	x	Current and forecast freezing precipitation.
Non-convective Turbulence	x				x	x	x	x			x		x	x	x	x	x	x			x	x			x	x			x	x				Location and nowcast of jet stream, mechanical, frontal and/or orographically-induced turbulence; clear air turbulence.
Volcanic Ash	x				x	x	x	x	x	x	x		x		x	x	x	x	x	x	x	x	x		x	x	x	x	x	x	x			Plume location, height and forecast.
Airport/Spaceport (Surface) Weather Reports	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		x	x	x		x		x	x	x	x	x	Routine and real-time surface observations from any source: domestic, military and international. METAR and SPECI. Does not include non-routine, off-net surface observations (e.g. ship reports).
Airport/Spaceport Terminal Forecasts[1]	x	x			x		x				x	x				x		x																Surface winds and visibility, sky condition (cloud amount, base, and type), and non-convective low-level wind shear. Includes convective activity, obstructions to vision and cloud cover.
Winds and Temperature Aloft	x				x	x	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x		x	x	x	x	x					Jet stream and tropopause location and forecast.
Clouds	x				x	x	x	x	x		x		x	x	x	x	x	x	x						x	x								Location and height of tops; cloud-top temperature.
Wake Vortex						x	x	x	x	x					x	x	x		x	x	x		x		x		x		x	x				Location and nowcast.
En Route Forecasts	x				x		x				x		x			x		x				x				x								Cloud bases and tops, convective activity, weather conditions and visibility.
Weather Alerts and Warnings	x				x	x	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x		x	x	x		x	x			x	Nowcasts of severe weather such as thunderstorms, tornadoes, hail, etc.
Space Weather Alerts, Warnings, and Forecasts											x		x			x	x	x																Geomagnetic storms, solar radiation storms, and radio blackouts.

Table 3.5 (continued)

Decision-Makers →	Aerospace Controllers (Space Operations Coordinators)					NAS Traffic Managers					Approach/Departure Traffic Managers					Air Route Traffic Managers					FSS Specialists					Airline Dispatchers				Airport Managers[1]		Spaceport Operators[2]		
Decisions → / Information Types ↓	Metering/Spacing	Route/Altitude Selection	Approach/Departure Route Selection	Approach/Departure Clearance	Reentry Clearance	Airport Acceptance Rate Determination	Ground-Stop/Delay Decision	Route Change	SWAP Implementation	Metering/Spacing Decision	Airport Acceptance Rate Determination	Ground-Stop/Delay Decision	Route Change	SWAP Implementation	Metering/Spacing Decision	Airport Acceptance Rate Determination	Ground-Stop/Delay Decision	Route Change	SWAP Implementation	Metering/Spacing Decision	Route/Altitude Selection	Go/No-Go (VNR)[3]	Runway Selection	Hazardous Weather Deviation	Escape Decision	Route/Altitude Selection	Deicing Decision	Go/No-Go Decision	In-flight Route Change	Airport, Runway, or Taxiway Closure	Cease Refueling Operations	Spaceport, Runway, or Taxiway Closure	Cease Refueling Operations	Information includes....
Thunderstorm (Deep Convection)	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		x	x	x		x	x		x		x	Location of precipitation and lightning (in-cloud, cloud-to-ground), hazardous weather information such as hail (including hail size), in-storm turbulence, echo tops, up/downdrafts, tornadoes, mesocyclones. Nowcast of convective initiation and precipita
Stratiform Precipitation Events	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		x	x	x		x	x					Cold season synoptic storm information. Widespread low-level visibility associated with advection fog, orographic stratus, valley fog.
Low-level Windshear	x		x			x					x					x						x		x	x			x						Location and nowcast of microburst and windshear; gust front and windshift line location.
In-flight Icing	x	x	x		x			x					x					x			x	x		x	x	x		x	x					Location, forecast and nowcast, including freezing level.
Surface Level Icing	x					x					x	x			x	x						x		x	x		x	x		x		x		Current and forecast freezing precipitation.
Non-convective Turbulence	x	x	x					x		x			x		x			x		x	x			x	x	x			x					Location and nowcast of jet stream, mechanical, frontal and/or orographically-induced turbulence; clear air turbulence.
Volcanic Ash	x	x	x		x	x	x	x	x		x	x	x	x		x					x	x		x	x	x		x	x	x		x		Plume location, height and forecast.
Airport/Spaceport (Surface) Weather Reports	x		x	x	x	x	x	x	x	x	x	x		x		x					x	x	x	x	x		x	x			x		x	Routine and real-time surface observations from any source: domestic, military and international. METAR and SPECI. Does not include non-routine, off-net surface observations (e.g., ship reports).
Airport/Spaceport Terminal Forecasts[1]	x	x			x	x	x		x		x	x		x		x	x		x		x	x				x		x	x					Surface winds and visibility, sky condition (cloud amount, base, and type), and non-convective low-level wind shear. Includes convective activity, obstructions to vision and cloud cover.
Winds and Temperature Aloft	x	x	x		x	x					x					x					x			x	x			x						Jet stream and tropopause location and forecast.
Clouds	x	x	x		x	x					x					x					x	x		x	x			x						Location and height of tops; cloud-top temperature.
Wake Vortex	x		x							x	x				x																			Location and nowcast.
En Route Forecasts	x	x	x		x	x					x	x				x	x	x	x	x	x	x				x		x						Cloud bases and tops, convective activity, weather conditions and visibility.
Weather Alerts and Warnings	x	x	x		x	x	x														x	x		x	x	x		x	x		x		x	Nowcasts of severe weather such as thunderstorms, tornadoes, hail, etc.
Space Weather Alerts, Warnings, and Forecasts		x	x	x	x																													Geomagnetic storms, solar radiation storms, and radio blackouts.

Table 3.5 (continued)

Information Type	Access by pilots/aerospace vehicle operators/specialists/dispatchers/FSS weather information prior to departure	Access to weather information by pilots/aerospace vehicle operators/FSS specialists/dispatchers in-flight	Current/nowcast weather information for ground operations	Provide common situational awareness for weather information (flight deck crew and ground personnel)	Provide current/nowcast/forecast weather information for approach/departure operations	Provide current/nowcast/forecast weather information for en route, oceanic, and aerospace operations [1]	Provide current/nowcast/forecast weather information for traffic flow management operations
Thunderstorm (Deep Convection)	X	X	X	X	X	X	X
Stratiform Precipitation Events	X	X	X	X	X	X	X
Low-level Windshear	X	X	X	X	X	X	X
In-flight Icing	X	X	X	X	X	X	X
Surface Level Icing	X	X	X	X	X	X	X
Non-convective Turbulence	X	X	X	X	X	X	X
Volcanic Ash	X	X	X	X	X	X	X
Airport/Spaceport (Surface) Weather Reports	X	X	X	X	X	X	X
Airport/Spaceport Terminal Forecasts[2]	X	X		X	X	X	X
Winds and Temperature Aloft	X	X		X	X	X	X
Clouds	X	X		X	X	X	X
Wake Vortex		X	X	X	X	X	X
En Route Forecasts	X	X		X	X	X	X
Weather Alerts and Warnings	X	X	X	X	X	X	X
Space Weather Alerts, Warnings, and Forecasts	X	X		X	X	X	

As seen from these tables, the aviation end-users have established the national and international need to detect and forecast operationally significant en-route and terminal weather events (in real time or near real time) on the surface and aloft that affect the safety, orderliness, and efficiency of aviation operations and disseminate the information to the appropriate decision makers. The weather phenomena that in general have the greatest impact on aviation operations, causing safety and delay problems, are:

- Adverse winds, including wind shear
- Wake vortex
- Severe non-convective turbulence
- In-flight icing
- Snow storms and surface icing
- Obstructions to vision (i.e., low ceilings and poor visibility)
- Convective activity (i.e., thunderstorms, lightning, heavy precipitation)

The following table, with slight modification, is taken from the *Mission Need Statement for Aviation Weather MNS #339,* and provides a more detailed enumeration of needed capabilities.

Table 3.6 Aerospace Weather Needed Capabilities

THUNDERSTORMS **Users -- ALL Identified Decision makers need these products.** En Route Controller, Oceanic Controller, Pilots (all types), Aerospace Vehicles Operators, A/D controller, Local Controller, Ground controllers, Aerospace controller, Traffic Manager, A/D and En Route traffic manager, Flight Service Station (FSS) Specialist, Airline Dispatchers, and Airport managers. **Need** – These user needs are 1. Current-time thunderstorm product, 2. Nowcast (zero-to-30-minute), 3. Forecast product (30 minute – 6 hour), and 4. Dissemination of thunderstorm products to users **Capabilities** – The following capabilities will aid decision makers by giving them the capability to mitigate avoidable weather delays by: ➢ Automatic detection of thunderstorm initiation, location and severity ➢ Location of precipitation and lightning (in-cloud, cloud-to-ground, and cloud-to-cloud) ➢ Detection and measurement of thunderstorm attributes (e.g., hail, turbulence, echo tops, up/downdrafts, tornadoes, meso-cyclones ➢ Providing information on thunderstorm cell movement & direction ➢ Providing regional current and forecast thunderstorm products ➢ Integrating weather products with aircraft targets on controller displays ➢ Automatic dissemination of products to pilots
OBSTRUCTIONS TO VISION **Users:** En Route Controller, Oceanic Controller, Pilots (all types), Aerospace Vehicles Operators, A/D controller, Local Controller, Ground controllers, Aerospace controller, Traffic Manager, A/D and En Route traffic manager, FSS Specialist, and Airline Dispatchers

Need: These users need 1. Graphical current-time visibility product (e. g., onset, density, visual range, etc.), 2. Graphical Forecast product, and 3. Dissemination of the Obstructions to Visibility products to users.

Capabilities – The following capabilities will aid decision makers by giving them the capability to mitigate avoidable weather delays by:

- Detection of visibility-impairing weather constraints (e.g., ceiling and/or visibility) with associated attributes
- Detection of advection fog, orographic stratus, and valley fog
- Determination of cloud tops and cloud cover
- Consolidation of remote observations of ceiling, visibility, temperature and dew point within 50 miles of pacing airports.
- Measurement of runway approach path visual range (slant visual range)
- Accurate and timely predictions of the onset, severity, and dissipation of low ceilings and visibility conditions
- Graphical current-time and forecast products
- Ability to automatically disseminate products to pilots

LOW-LEVEL WIND SHEAR

Users: En Route Controller, Oceanic Controller, Pilots (all types), Aerospace Vehicles Operators, A/D controller, Local Controller, Ground controllers, Aerospace controller, NAS Traffic Manager, A/D and En Route traffic manager, FSS Specialist, and Airline Dispatchers

Need: These users need a 1. Wind shear/microburst current-time product, 2. Wind shear/microburst forecast product, 3. Terrain-induced windshear and turbulence current-time product, 4. Distribution of wind shear products (current product and forecast product) from wind shear detection systems to adjacent airport within the range of the detection system, and 5. Dissemination of Wind shear/microburst products to users

Capabilities: The following capabilities will aid decision makers by giving them the capability to mitigate avoidable weather delays by:

- Distribution of wind shear/microburst products from TDWR and ASR-WSP to adjacent airports
- Dissemination to users of wind shear/microburst alerts generated from LLWAS, TDWR, and ASR-WSP and other detection system specially tailored to specific airports

IN-FLIGHT ICING

Users: En Route Controller, Oceanic Controller, Pilots (all types), Aerospace Vehicles Operators, A/D controller, Local Controller, Ground controllers, Aerospace controller, NAS Traffic Manager, A/D and En Route traffic manager, FSS Specialist, and Airline Dispatchers

Need: These users need icing location, including freezing level. 1. En Route/Oceanic current-time icing product, 2. En Route/Oceanic forecast icing product, and 3. Dissemination of products to users

Capabilities: The following capabilities will aid decision makers by giving them the capability to mitigate avoidable weather delays by:

- Ability to detect and predict, in high-resolution, icing areas by location, horizontal/vertical extent, duration, and potential severity.
- Automated dissemination of pilot reports (Auto PIREP)
- Automated distribution of airborne sensor outputs
- Automated ability of Controller to enter manually-received PIREP into system

SNOW AND ICE PRODUCTS

Users: En Route Controller, Oceanic Controller, Pilots (all types), Aerospace Vehicles Operators, A/D controller, Local Controller, Ground controllers, Aerospace controller, NAS Traffic Manager, A/D and En Route traffic manager, FSS Specialist, and Airline Dispatchers

Need: Current and forecast freezing precipitation. 1. Current-time snow and ice product, 2. Forecast snow and ice product, and 3. Dissemination of Snow and Ice Products to users

Capabilities. The following capabilities will aid decision makers by giving them the capability to mitigate avoidable weather delays by:

- Expanding coverage area of accurate surface observations of
  - Winds
  - Frozen precipitation
  - Temperature
  - Humidity
- Developing snow/ice forecast times out to 6-12 hours
- Implementing Weather Support Deice Decision Making (WSDDM) at pacing airports

NON-CONVECTIVE TURBULENCE AND WINDS ALOFT

Users: En Route Controller, Oceanic Controller, Pilots (all types), Aerospace Vehicles Operators, A/D controller, Local Controller, Ground controllers, Aerospace controller, NAS Traffic Manager, A/D and En Route traffic manager, FSS Specialist, and Airline Dispatchers

Need: Location and nowcast of jet stream, mechanical, frontal and/or orographically induced turbulence; clear air turbulence and tropopause location and forecast. 1. Current-time Non-convective Turbulence and Winds Aloft Product, 2. Forecast Non-convective Turbulence & Winds Aloft Product, and
3. Dissemination of Non-convective Turbulence & Winds Aloft Products to users

Capabilities. The following capabilities will aid decision makers by giving them the capability to mitigate avoidable weather delays by:

- Enhanced observation and predictive capabilities of location and severity of non-convective turbulence
- Automated ability of controller to enter manually-received PIREPs into system
- Automated collection and downlink of pilot reports (Auto PIREP)

VOLCANIC ASH

Users: En Route Controller, Oceanic Controller, Pilots (all types), Aerospace Vehicles Operators, A/D controller, Local Controller, Ground controllers, Aerospace controller, NAS Traffic Manager, A/D and En Route traffic manager, FSS Specialist, and Airline Dispatchers

Need: Plume location, height and forecast. 1. Current-time product, 2. a plume forecast product, and 3. the dissemination of products to users.

Capabilities. The following capabilities will aid decision makers by giving them the capability to mitigate avoidable weather delays by:

- Detection and tracking of volcanic ash plume location, height, horizontal/vertical extent, and forecast.
- Dissemination of products to users

AIRPORT SURFACE WEATHER REPORTS

Users: En Route Controller, Oceanic Controller, Pilots (all types), Aerospace Vehicles Operators, A/D controller, Local Controller, Ground controllers, Aerospace controller, NAS Traffic Manager, A/D and En Route traffic manager, FSS Specialist, and Airline Dispatchers

Need: Routine and real-time surface observations from any source: domestic, military and international. Meteorological Terminal Aviation Routine Weather Report (METAR) and Aviation Selected Special Weather Report (SPECI).

Capabilities. The following capabilities will aid decision makers by giving them the capability to mitigate avoidable weather delays by:

- Ability to detect routine and real-time surface conditions
    - Surface winds,
    - Visibility,
    - Sky condition (cloud amount, base, and type), and
    - Cloud cover
- Ability to disseminate observation to the appropriate users
- Ability to interface with the necessary weather product generators

AIRPORT TERMINAL FORECASTS

Users: En Route Controller, Oceanic Controller, Pilots (all types), Aerospace Vehicles Operators, A/D controller, Local Controller, Ground controllers, Aerospace controller, NAS Traffic Manager, A/D and En Route traffic manager, FSS Specialist, and Airline Dispatchers

Capabilities. The following capabilities will aid decision makers by giving them the capability to mitigate avoidable weather delays by:

- Providing advanced notice of changing wind conditions to permit timely change of active runways

Wake Vortex

Users: En Route Controller, Oceanic Controller, Pilots (all types), Aerospace Vehicles Operators, A/D controller, Local Controller, Ground controllers, Aerospace controller, NAS Traffic Manager, A/D and En Route traffic manager, FSS Specialist, and Airline Dispatchers

Capabilities. The following capabilities will aid decision makers by giving them the capability to mitigate avoidable weather delays by:

- Providing terminal 3-D wind and temperature fields

4 Review of Colombian aviation meteorology system

4.1 Summary of airports and services

Table 4.1 summarizes critical information for the 47 controlled airports operated by UAEAC, along with corresponding information for the single, privately operated controlled airport in Colombia. This table was developed cooperatively with UAEAC staff after extensive discussions. The airports are separated into geographical groups on the basis of UAEAC's six administrative regions. Within each region, the airports are listed in order of the annual number of flight operations (landings or takeoffs), using data from 2003. The airports serving as regional centers are indicated by asterisks (*) and printed in **bold** type. Airports that are classified as "international" by the CAR/SAM Basic ANP are identified by the abbreviation INTL following the airport name. Airports designated in the Colombian AIP (posted online on the UAEAC web page: http://www.aerocivil.gov.co/) to provide MET services are indicated in the AIP-MET column. Currently, seven airports are equipped for instrument landings (ILS Categories I and II), and two additional airports are being upgraded to ILS service in the near future (arrows in the ILS Category column indicate planned enhancements).

Only five Colombian airports operate around the clock, with the remaining controlled airports (43 in all) being restricted to daytime and early evening operations – generally from 0600 to 1800 local time.

Terminal area forecasts (TAFs) are issued for seven of Colombia's eight international airports. The one exception is Cúcuta, located in northeastern Colombia at the Venezuelan border.

With only two exceptions, Corozal and Mariquita, all of the UAEAC controlled airports make weather observations and issue hourly METARs during their hours of operation. Radiosondes are launched at three airports. There is also a sounding system at a fourth airport, Riohacha, but that system is not currently in use. Radiosondes are released once a day at approximately 0630 local time for the official 12Z sounding.

At twenty-seven (27) of the 45 controlled airports that issue METARs, IDEAM provides MET services with full-time, trained meteorological observers according to the inter-institutional agreement. At the remaining 18 airports the METARs are generated by UAEAC staff that have been trained as weather observers through the AIS/COM/MET Integral course, but make their weather observations as a collateral, or secondary, job. In many of these cases, the METARs are prepared by the tower controllers. The three right-hand columns in this table summarize the number of IDEAM MET staff assigned to each airport, the total number of UAEAC (with AIS, COM, and MET responsibilities), and the number of UAEAC staff who are directly involved in making meteorological observations and preparing METAR reports (including part time assignments).

Table 4.1 Summary information for controlled airports in Colombia

regional	siglas	AEROPUERTO	2003 Operations	ILS Category	Airport Hours	ATC Controlled	MET Hours	12 Z Radiosonde	TAF	METAR	Aerocivil AIS/COM/MET	Aerocivil MET Staff	IDEAM MET Staff
Antioquia	SKMD	MEDELLIN ✓	82,426		0600-1800	X	0600-1800			IDEAM	8		3
	SKRG	**RIONEGRO*** INTL ✓	45,113	Cat I → II	24	X	24		X	IDEAM	8		5
	SKUI	QUIBDO ✓	13,002		0600-1800	X	0600-1800			IDEAM			2
	SKMR	MONTERIA	12,012		0600-1900	X	0600-1800			IDEAM	1		3
	SKLC	CAREPA (Los cedros) APARTADO	11,504		0600-1800	X	0600-1800			IDEAM	2		2
	SKMZ	MANIZALES	9,831		0600-1800	X	0600-1800			UAEAC	2	1	
	SKBS	BAHIA SOLANO	4,057		0600-1800	X	0600-1800			UAEAC	2	1	
Atlantico	SKCG	CARTAGENA INTL ✓	31,634	→ Cat I	24	X	24		X	IDEAM	5		6
	SKBQ	**BARRANQUILLA*** INTL ✓	26,559	Cat I	24	X	24		X	IDEAM	13		5
	SKSM	SANTA MARTA	12,768		0600-2200	X	0600-2200			IDEAM	2		3
	SKSP	SAN ANDRES INTL ✓	12,153	→ Cat I	0600-2400	X	0600-1800	X	X	IDEAM	3		5
	SKVP	VALLEDUPAR	6,635		0600-1800	X	0600-1800			IDEAM			3
	SKCZ	COROZAL	4,848		0600-1800	X	—			—	2		
	SKPV	PROVIDENCIA ✓	3,132		0600-1800	X	0600-1800			IDEAM	2		2
	SKRH	RIOHACHA	2,176		0600-1800	X	0600-1800	X		IDEAM			2
Bogota	SKBO	**BOGOTA D.C.*** INTL ✓	195,734	Cat I & Cat II	24	X	24	X	X	IDEAM	4	1	23
	SKGY	GUAYMARAL ✓	60,472		0600-1800	X	0600-1800			UAEAC	2	1	
	SKGI	GIRARDOT	19,360		0600-1800	X	0600-1800			UAEAC	2	1	
	SKIB	IBAGUE	18,658		0600-2000	X	0600-2000			IDEAM	1		2
	SKNV	NEIVA	18,193		0600-2000	X	0600-1800			IDEAM	2		3
	SKQU	MARIQUITA	17,725		0600-1800	X	—			—	2		
	SKAS	PUERTO ASIS	6,900		0600-1800	X	0600-1800			UAEAC	2	1	
	SKFL	FLORENCIA	6,688		0600-1800	X	0600-1800			UAEAC	1	1	
	SKSV	SAN VICENTE DEL CAGUAN	3,046		0600-1800	X	0600-1800			UAEAC	2	1	
	SKLT	LETICIA INTL ✓	2,640	Cat I	0600-2000	X	0600-2000	X	X	IDEAM	1		4
Valle	SKCL	**CALI*** INTL ✓	46,279	Cat I	24	X	24		X	IDEAM	11		5
	SKPE	PEREIRA	22,199		0600-2200	X	0600-2200			IDEAM	4		3
	SKAR	ARMENIA	10,739		0600-2100	X	0600-2100			IDEAM	2		3
	SKPS	PASTO ✓	7,646	→ Cat I	0600-1800	X	0600-1800			IDEAM			2
	SKPP	POPAYAN	7,458		0600-1800	X	0600-1800			UAEAC	2	1	
	SKCO	TUMACO	5,715		0600-1800	X	0600-1800			UAEAC	2	1	
	SKCO	CARTAGO	3,298		0600-1800	X	0600-1800			UAEAC	2	1	
	SKIP	IPIALES	1,396		0600-1800	X	0600-1800			IDEAM			3
	SKGP	GUAPI	1,152		0600-1800	X	0600-1800			UAEAC	2	1	
	SKBU	BUENAVENTURA	1,034		0600-1800	X	0600-1800			UAEAC	2	1	
Santander	SKBG	BUCARAMANGA ✓	27,614	→ Cat I	0600-2200	X	0600-2200			IDEAM	5		4
	SKCC	**CUCUTA*** INTL ✓	15,056	Cat I	0600-1900	X	0600-1900			IDEAM	3		3
	SKEJ	BARRANCABERMEJA	10,157		0600-1800	X	0600-1800			IDEAM			3
	SKUC	ARAUCA	9,878		0600-2000	X	0600-1800			IDEAM	2		2
	SKSA	SARAVENA	5,905		0600-1800	X	0600-1800			UAEAC	2	1	
	SKTM	TAME	2,945		0600-1800	X	0600-1800			UAEAC	2	1	
	SKOC	OCANA	879		0600-1800	X	0600-1800			UAEAC	2	1	
Meta	SKVV	**VILLAVICENCIO*** ✓	39,828		0600-1800	X	0600-1800			IDEAM	4		3
	SKYP	EL YOPAL	29,967		0600-1900	X	0600-1800			UAEAC	2	1	
	SKSJ	SAN JOSE DEL GUAVIARE	16,047	Cat I	0600-1800	X	0600-1800			UAEAC	2	1	
	SKMU	MITU	5,463		0600-1800	X	0600-1800			UAEAC	2	1	
	SKPC	PUERTO CARRENO	822		0600-1800	X	0600-1800			IDEAM	2		2
			829,379								**124**	**19**	**106**
Private	SKLM	La Mina (CERREJON)			0600-2100	X							

***Regional Center** ✓ **Identifies airports visited by EarthSat team** **Note: Riohacha radiosonde station is not in active use**

4.2 Meteorological Observing Systems

4.2.1 Airport Surface Observations – METARs

The bulk of Colombia's efforts in aviation weather are centered on the timely collection and distribution of METARs. These efforts are usually quite successful and reflect well on the dedication and professionalism of the IDEAM and AeroCivil observers.

The data collection system at the airports, however, is complicated by multiple measurement systems and habits developed through years of work.

Virtually all controlled Colombian airports have some combination of three different basic observing systems.

(1) The most basic airport MET system in Colombia consists of wind socks along the runway, a tower altimeter, and an anemometer (wind speed and direction) mounted on top of the control tower. These basic systems were apparently installed by AeroCivil as part of the initial airport design and date back to the construction of the control tower. While most of these MET systems are relatively old, they seem to be in good working order due to their original high quality and their location in the controlled environment of the air traffic control tower. The top of the control tower is not, however, a good place to make airport wind measurements. By ICAO guidelines the preferred wind measurement locations are along the runway, near the touchdown zone, at a standard height of 6-10 meters. Airport control towers, on the other hand, are usually significantly displaced from the runway and are of variable height — frequently much greater than 10 meters. These basic weather systems, however, should be maintained as backup instruments even after newer, better-located systems are installed. Even today, these tower instruments are the only MET systems available at Colombia's smaller airports (see Figures 4.1 & 4.2).

Pasto (Myers)

Rionegro (Johnson)

Figure 4.1 Control tower anemometer and classic dial displays.

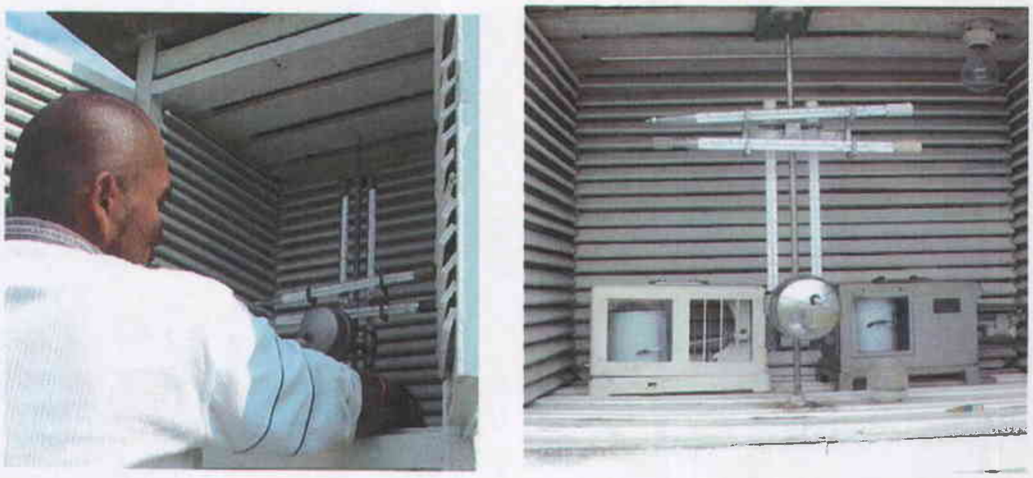
Cúcuta (Myers)

Figure 4.2 Modern replacement control tower anemometer and altimeter displays.

(2) At larger airports where IDEAM staff are assigned there is frequently a special instrument enclosure installed by IDEAM for making routine synoptic and climatological observations. This is a prepared, fenced area that is usually termed the "MET Garden" (see Figures 4.3 to 4.6). In its basic configuration this is a totally manual observing station with hourly observations made by qualified observers. Within an airport environment it can be difficult to find clear, open locations that are convenient to the airport weather offices, so these instrument sites often do not have ideal exposure.

Pasto (Myers)

Figure 4.3 IDEAM "MET Garden" at Pasto's Antonio Narino Airport.



Medellín (Johnson) *Cúcuta (Myers)*

Figure 4.4 IDEAM "MET Garden" instrument shelters.

Rionegro (Johnson) *Cúcuta (Myers)*

Figure 4.5 IDEAM "MET Garden" sun duration and solar radiation instruments.

Cúcuta (Myers) *Pasto (Myers)*

Figure 4.6 IDEAM "MET Garden" evaporation pan and tipping bucket rain gauge.

Though the MET Gardens are not necessarily located at ideal observing locations, IDEAM observers frequently prefer to use manual observations from the Met Gardens for preparing METARs. In addition to their possible role in METAR creation, the MET Gardens also generate a variety of climatological measurements that often make use of chart recordings (ink and paper) that have to be collected, analyzed, and summarized for IDEAM's climatological records, archival, and dissemination to international climate networks (see Section 3.3).

In recent years, some of the airport MET Gardens have been enhanced by the addition of elementary automatic weather stations supplied by Sutron Corporation (Fig. 4.7). These enhanced systems make automatic observations of temperature, pressure, and wind (direction and speed) and relay the measurements to the airport weather office via a radio link. The principal value of these automatic systems is that the observers don't have to go outside to make a reading. The automatic systems are installed within the existing MET Garden and include a standard height 10 m tower for wind measurements. The system includes a PC-based system unit installed in the weather office that displays the real-time data and provides software to assist the observer in generating correctly formatted METARs. While these systems make it easier to prepare METARs, the MET observers still have to add additional information to the METAR – such present weather, visibility, cloud coverage and height – which are all based on manual observations by the trained observers.

Figure 4.7 IDEAM solar powered automatic weather station, showing the solar panel, instrument box (with pressure sensor), and temperature sensor housing.

Rionegro (Johnson)

At most of the airports we visited the IDEAM observers have continued to make their manual hourly observations from the standard equipment even after the automatic systems are installed, and they only look at the automatic readings as a comparison. The observers frequently don't trust the new systems and prefer to use manual observations for generating METARs. At airports where individual weather instruments may have failed or where the MET observer doesn't have access to a display for a measurement system, the observer will routinely phone the control tower and ask for their readings for wind or pressure and use those values in their METARs. In general there seems to be a widespread distrust of the new systems, in large part due to the lack of sustained system maintenance and calibration efforts. Airport observers are left to make their own decisions as to which measurements are to be trusted, a decision that is complicated by a lack of training to acquaint the observers with where observations should be made to be best representative of the airport's landing and takeoff areas.

(3) In the past year, AeroCivil installed new Sutron automatic weather stations at 12 Colombian airports (see Figs. 4.8 and 4.9). These newer observing systems have, in fact, been installed at more appropriate locations near the runway (though not always near the touchdown point). Like the Sutron systems installed in the MET Gardens, these systems communicate their observations to the weather office over a radio link. These systems have also been upgraded from Colombia's earlier Sutron systems and have dual pressure sensors and an improved air intake for the pressure measurements that should reduce possible dynamic pressure (wind) effects. These systems are also equipped with VHF ATIS radios for short range transmission of METARs to nearby aircraft. These new Sutron system also support duplicate displays of the weather observations through PC's installed in the airport Control Tower and Approach Control.

For the most part, IDEAM observers at airports where these new Sutron systems have been installed do not know very much about the systems. As is the case with the automatic observations in the MET Garden, IDEAM observers tend to distrust the newer Sutron instruments. When differences occur between manual and automated observations, the observers tend to use the manual observations with which they are more familiar. The differences do not seem to be studied by the observers so that a rational decision can be taken about which instrument to use, nor are calibration and quality control procedures generally understood. The need for more training on these systems is obvious.

In examining the 2003 Sutron automatic weather systems, we identified two specific areas of concern. First, the ATIS system generates an audible playback of the ATIS broadcast in the weather office. This quickly gets annoying and some observers turn off the entire ATIS system to stop the noise. After checking with both Sutron and their local representative (Apcytel Ltda), we learned that there is a control that can be used to turn down the speaker volume, but the system specifications mandated that the speaker be audible at all times so users were either discouraged from turning down the volume or not shown how to do so. There needs to be a reexamination of the ATIS procedures to ensure that the ATIS systems can be used without interfering with weather office operations. Subsequent to our initial visits, UAEAC began to correct this problem.

Rionegro (Johnson)

Leticia (Foote)

Guaymaral (Henderson)

Figure 4.8 AeroCivil automatic weather station showing the exterior (upper-left), interior (lower), and MET office display (upper-right).

The second problem we noticed was that the Sutron displays which were installed in the control tower and approach control are merely slave copies of the display in the MET office. When the MET observer prepares a METAR, he opens a dialogue box which obscures much of the normal screen display. This limits the usefulness of the remote displays and makes it difficult to read critical weather information when the observer is preparing a METAR. A better design would be to have the main system computer in the MET office create a special end-user tower display that would maintain a correct real-time display of MET data and recent METARs. Such a display could also be designed to use large character displays for easy reading in the tower environment. Such custom displays would speed acceptance of the new systems by providing weather information that is easy to read and clearly visible from all controller positions within the tower or approach control. Subsequent to our initial visits UAEAC began talks with Apcytel/Sutron about improving the control tower displays.

In general there is a lack of confidence in the new observing systems. In part, this is due to a combination of maintenance problems, individual sensing systems that are broken or out of calibration, and readings that differ from system to system. Given the variability in the locations of these sensor packages, it is not surprising that the systems frequently give different readings. Rather than distrust all the new systems, however, there needs to be a careful calibration and inter-comparison of the measurement systems leading to a clear decision of which measurement system provides the best operational data. At that point, the preferred system should be used for all official observations. When systems are out of repair, they need to be fixed, even if they are out of warranty.

At many airports, the MET observing systems include a variety of instruments of various ages. Instruments that have stopped working long ago still clutter the airfield, alongside newer instruments. Some older instruments, including some that are still in use, are not even maintained on the IDEAM and AeroCivil inventories.

Once it is clarified which systems are preferred for operational use, old, defective, or out of service systems should be removed.

Maintenance. System maintenance is a major problem. It appears that new systems are purchased with a two-year warranty during which time the equipment supplier maintains the system. After the warranty period ends, however, very little additional maintenance – either preventive or repair – seems to get done. This then introduces a cycle of acquisition (to the lowest bidder) and replacement after only a few years instead of a more cost effective approach of buying high quality systems and them maintaining them for long-term service. The standard tower altimeters seem to fall into this later category and many of them are still working fine after a quarter of a century or more. High quality meteorological instruments shouldn't have a lifetime of only a few years, even in the Colombian environment.

Rionegro (Johnson) *Quibdó (Johnson)*

Figure 4.9 Old and new instrument towers share the same enclosure at Rionegro (left) and unusable sensors reflect years of neglect at Quibdó (right).

The problems with system maintenance are compounded by the overlapping instrument systems provided by IDEAM and UAEAC, and by the MET observers' low expectations that defective items will be repaired. These issues seem to translate into a hesitancy to report equipment problems and even an uncertainty as to whom the problems should be reported.

On 11 March 2004 UAEAC created the "Grupo de Ingeniería de Mantenimiento y Ayudas a la Meteorología" to start to address some of these problems.

RVR and Ceiling Observations. Although not currently integrated into the Sutron automatic weather stations, there are a number of runway visual range (RVR) and ceilometer systems installed at Colombian airports. In our experience visiting Colombian airports, however, we discovered that most of these systems do not appear to be operational, and are frequently described by airport staff and pilots as out of service.

The RVR and ceilometer systems are very important and need to be maintained in an operational condition. The lack of required RVR measurement systems was highlighted as a deficiency of the Colombian Aeronautical Meteorology system by the CAR/SAM Regional Aeronautical Meteorology Subgroup (AERMETSG/6) in their sixth meeting (June 2003) in Brasilia, Brazil. These systems are required at all of Colombia's International Airports (CAR/SAM ANP MET Requirements, Table AOP 1 and Annex 3, 4.7.3 and 4.7.4) and are also needed at all airports with ILS systems to ensure that instrument landings are only attempted within the correct range of meteorological conditions. For reference, Table 4.2 summarizes the RVR minimums mandated for each class of ILS. An accompanying high quality ceilometer is also important for helping define the limits of airport operation for non-instrument approaches and to provide the tower a continuously updated, high-quality ceiling observation.

Table 4.2: Approach Category/Minimum RVR

Category	Visibility (RVR)
Non-precision	2,400 feet
Category I	1,800 feet
Category II	1,200 feet
Category IIIa	700 feet
Category IIIb	150 feet
Category IIIc	0 feet

source: FAA Aeronautical Information Manual (online)

RVR, or other visibility systems, and ceilometers are also needed at a number of high volume airports that have acknowledged problems with fog, low cloud, and visibility — such as Medellín and Bucaramanga. Although Guaymaral is a general aviation airport that is only open for VFR flying, it could also benefit from routine visibility and ceilometer observations.

While RVR and ceilometer instruments can be purchased as stand-alone instruments, it may be better to incorporate these instruments into the airports' automatic observing systems to facilitate the efficient preparation of accurate METARs.

Data Distribution. At airports with Sutron automatic weather stations, METARs are usually prepared using the Sutron workstation, with the automatically recorded readings being augmented by ceiling, visibility, cloud cover and current weather information that are added by the operator/observer. These METARs are typically written on a piece of paper (or communicated by voice over telephone or radio) and given to the AFTN operator who retypes the entry into the AFTN system. In some cases the METARs are communicated by voice (over a telephone line or radio) to an AFTN operator at another airport. IDEAM MET observers also log into the IDEAM web page and reenter the same METAR into IDEAM's web-based data entry application in order to get the METAR into the IDEAM data base. These multiple data entry and retyping are time consuming and prone to introduce typographical errors into the METAR.

For future CNS/ATM applications it will be necessary to automate this system through networking of the data preparation workstations and the data transmission portals (AFTN, WAFS, or web-based interface with IDEAM). This will ensure a more timely distribution of data, with increased accuracy. As part of this process, the METARs (and other observations such as radiosondes encoded into TEMP format, TAFs and so on) should be prepared using computer templates that assist the user in preparing correctly formatted products, and that can also scan the final product for errors prior to transmission.

4.2.2 Upper Air Soundings

Meteorological soundings are among the most important observational systems for modern meteorology. National soundings are a critical contribution to the international meteorological system (World Weather Watch), and of direct and immediate importance to Colombia. The soundings provide direct input into the global numerical weather prediction models that form the core of the global forecast system. Providing high-quality soundings for model initialization improves model results and accuracy over Colombia. In addition, local soundings are critical for forecasting the formation and movement of rain storms and thunderstorms. Unfortunately, we received the distinct impression that upper air soundings are currently not being used to their full potential in Colombia.

The Colombian radiosonde network is well designed with regard to the number of sounding sites and their placement around the country. Officially, the Colombian upper air system includes five radiosonde stations, extending from San Andrés in the northwest to Leticia to the southeast, giving good coverage across an important geographical region (see Table 4.3). San Andrés is a Colombian island in the northwest Caribbean, approximately 700 km away from the Colombian coastline. Bogotá is in Colombia's central highlands and Leticia is far to the south, on the Amazon River at 4 degrees south latitude. The two remaining stations are at Riohacha, on Colombia's Caribbean coast, and Las Gaviotas which is located in Colombia's eastern plains. All of the sounding sites, except Las Gaviotas, are located at airports. Unfortunately, Las Gaviotas and Riohacha have not been taking regular soundings for some time and have to be regarded as inactive. The current operational network therefore consists of three radiosonde stations, as listed in Table 4.3. Soundings are taken at 1200Z only.

Table 4.3
Colombian Radiosonde Stations

City	*Latitude*	*Longitude*
San Andrés	12°35" N	81°42" W
Bogotá	4°42" N	74°09" W
Leticia	4°12" S	69°56" W
Riohacha	11°32" N	72°56" W
Gaviotas	4°33" N	70°55" W

(inactive stations are shaded gray)

Cost is one principal limit to launching more radiosondes. The cost of the sonde itself is the most critical cost, with the hydrogen used to inflate the balloon being produced by a local, on-site hydrogen generator.

Because of the important location of San Andrés, in what would otherwise be a data void in the midst of the Caribbean, the U.S. National Weather Service (NWS) has assisted Colombia by providing a radiosonde system for San Andrés, currently a InterMet IMS-1500 Radiotheodolite system (see Figs. 4.10 and 4.11). The NWS is also supplying the station with Sippican B2 radiosondes from the U.S. inventory. The Sippican B2 sonde is used at many NWS radiosonde sites in the United States.

San Andrés (Foote) *San Andrés (Foote)*

Figure 4.10 San Andrés radiosonde station (left) and radiotheodolite (right).

Figure 4.11 Hydrogen generator for Leticia radiosondes.

Leticia (Foote)

Bogotá and Leticia both use Vaisala sounding systems (MW15), with a DigiCORA II processing system and RS80-15G (GPS wind-finding) sondes. While we did not visit Riohacha and Las Gaviotas, we understand that they also have Vaisala systems (one MW-15 DigiCORA II system and one older model MW-11 DigiCORA I system).

Since upgrading to the GGS wind-finding sonde, the Bogotá radiosonde system has had a problem with radio interference to the GPS readings at the lowest altitudes in the sounding, causing the system to lose the low level winds. This is a relatively common problem with the older RS80 model GPS wind finding sondes and can be solved by moving the launch site to a different location, or by upgrading to Vaisala's all-digital RS92 sondes.

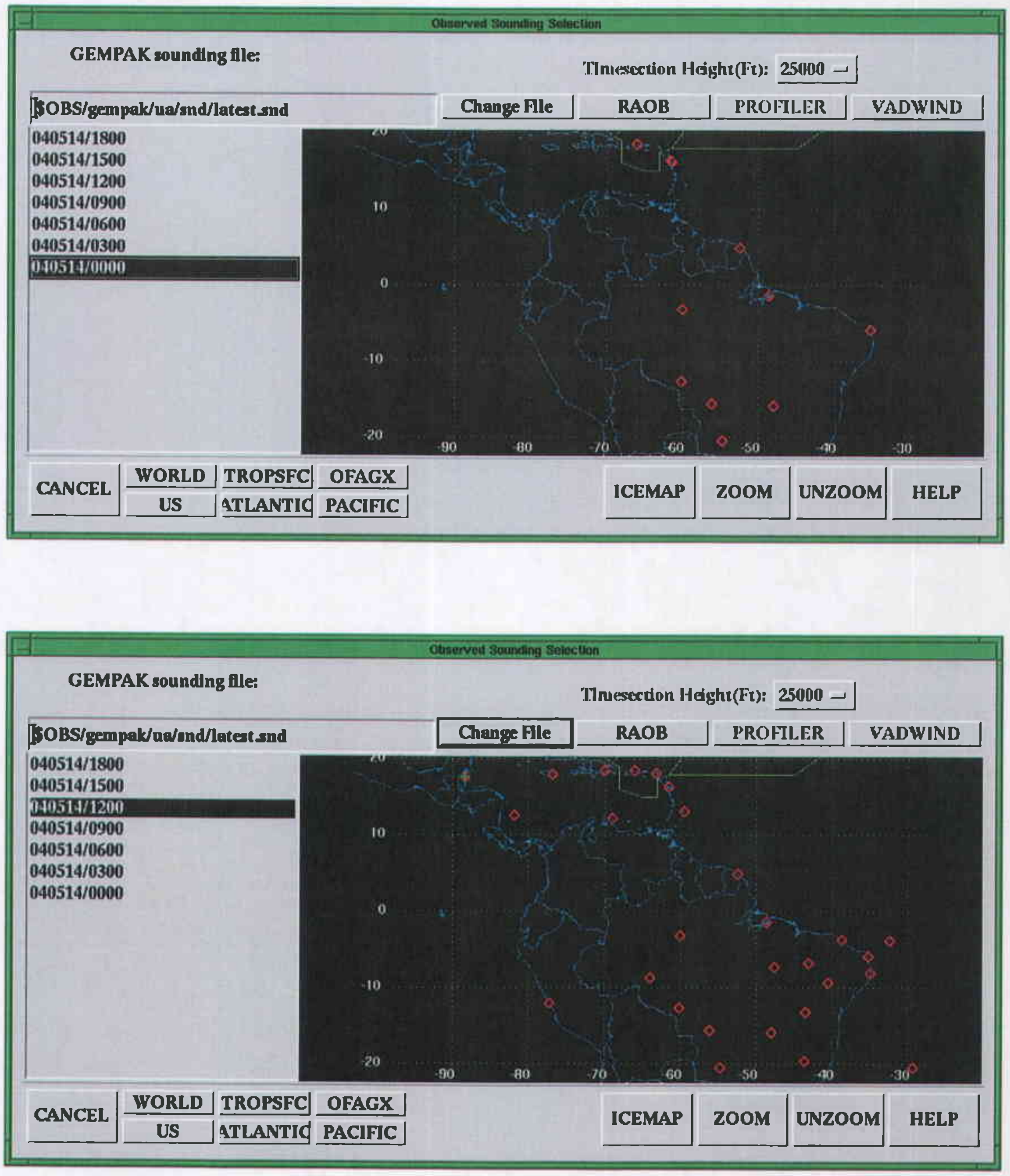
The RS80 series of sondes is an analogue system that will be discontinued in the near future, most likely in 2005. Based on discussions with Vaisala, we understand that the RS92 sondes are improved in a number of ways, with better humidity sensors and improved, 12-channel code correlation GPS receiver for better wind finding and reduced problems with RF interference. While the RS92 sondes are approximately the same cost as the older RS80 sondes, they are a full digital system and require an extensive upgrade of the ground station components. We understand that there are two basic upgrade paths. The first option is a relatively modest upgrade of the MW-15 ground station to be able to receive and process data from the RS92 sonde. The other option is a total upgrade of the system to the MW21 DigiCORA III system that was designed for use with the RS92 sonde. The DigiCORA III system uses a standard PC as the data processing platform which allows the radiosonde system to be networked to other workstations so it can transmit soundings electronically to meteorologist workstations and to gateway machines for transmitting the soundings to national and international data centers without manual reentry of the processed (TEMP format) sounding.

With the movement of international upper air sounding systems to higher-resolution GPS wind-finding, there is a recognized need to move from the existing TEMP format to BUFR format which can efficiently encode much larger data files (see WMO Document CIMO/OPAG-UPPER-AIR/ET UGRN-1/Doc.5.3). This transition to a new data format will require software upgrades to the radiosonde ground stations and put a premium on ground stations that can transfer processed soundings electronically without manual reentry of the data.

Given the short remaining lifetime of the RS80 sondes, it may be prudent to upgrade the Bogotá system to the DigiCORA III system with RS92 sondes as soon as possible, rather than trying to find a new radiosonde release point in the vicinity of Bogotá without RF interference. Plans should also be made to upgrade the remaining Vaisala systems for compatibility with the RS92 sonde.

Ideally, radiosondes should be launched twice a day from each upper-air site, at 0Z and 12Z. The official WMO summary of national observing systems (WMO Publication #9, Weather Reporting, Volume A - Observing Stations) shows a commitment by Colombia to launch two soundings a day in Bogotá, and single soundings (at 12Z) at each of the other four official radiosonde sites. Unfortunately, the resources for a full launch schedule are not available. This is a common problem throughout the world, including South America, and radiosondes are frequently only launched once a day. For use in forecasting convection, the morning sounding (12Z) is preferred so most stations that have to choose a reduced launch schedule launch a 12Z sounding. The following illustration, for example shows the number of radiosondes launched in northern South America on Friday, May 28, at 0Z and 12Z (see Figure 4.12).

With the higher density of soundings at 12Z, the selection of a 12Z sounding provides better data for model initiation since it is generally better to have one very good initialization field every day, instead of two less detailed initializations.



data provided by Aviation Weather Center, NOAA

Figure 4.12 Soundings taken at 0Z (top) and 12 Z (bottom) on May 28, 2004.

In this particular example, it is also interesting to note that only one Colombian radiosonde (San Andrés, at 12Z) made it into the international data system even though the IDEAM database for the day indicated that a sounding was also collected at Bogotá at 12Z.

For making future improvements in the Colombian radiosonde system, the first priority should be finding support to launch one radiosonde a day (12Z) from the four airport launch sites. The Riohacha radiosonde site is important for monitoring tropical cyclone effects and for providing valuable climate data sets (WMO, 2003, and Douglas *et al*, 2004). Only after all supported sounding sites are able to launch daily sounding should a site, such as Bogotá, consider launching two soundings a day.

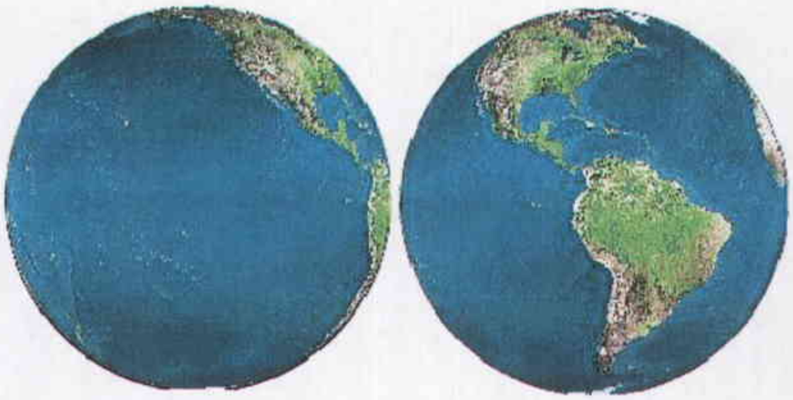
Even though it is not located at an airport, soundings from Las Gaviotas would be important for forecasting convective activity and should be activated, if possible. If this system could be better supported at an airport site, the radiosonde equipment at Las Gaviotas could be relocated to one of the small airports in eastern Colombia, such as San José del Guaviare, Puerto Inirida, or Puerto Carreño.

The balloon soundings taken at the three sites in Colombia have great inherent value for making local forecasts. However, it that little use is being made of the soundings. This is a major operational shortcoming since sounding are a critical observation for accurately forecasting convective storms. The starting point for sounding analysis is a plotted sounding on a thermodynamic diagram such as a skew-T. In reviewing forecasting operations in Colombia we also discovered that while skew-T plots could be generated at IDEAM headquarters, in downtown Bogotá, there was no software available at the OPMET Forecast Center at El Dorado Airport or other radiosonde sites to plot a skew-T or display one on a workstation screen. In follow up discussions with Vaisala we learned that their METGRAPH software for plotting soundings does not support skew-T/log-P or other thermodynamic diagrams on their DigiCORA II (MW15) systems. This capability is only available on their DigiCORA III (MW21) systems. As a priority, IDEAM and AeroCivil should either acquire 3rd Party plotting software that can produce high-quality upper-air soundings or upgrade to DigiCORA III with METGRAPH.

It is also clear that there is a need for a training program to encourage the full use of available upper-air soundings in the aviation forecasting process in Colombia.

4.2.3 Satellite Receiving Stations

The operational GOES-12 satellite (also called GOES-EAST) is positioned almost directly over Colombia (see Figure 4.13). This means that Colombia is in a unique position to receive the highest quality satellite imagery of any country in North or South America. The satellite is also important in that it provides uniform coverage over all regions of the country. Making full use of the GOES imagery and sounding products should be a high priority for Colombia.



(Illustration courtesy of NESDIS)

Figure 4.13 Earth views from the GOES-WEST and GOES-EAST geostationary satellites.

The OPMET Forecasting Center at Bogotá's El Dorado Airport receives GOES/GVAR imagery from a GVAR receiving system located at IDEAM's offices in downtown Bogotá. AeroCivil also receives its own GOES/GVAR imagery from a Systems West receiving station located at the airport. There is also a separate Systems West WEFAX receiving station that is not functioning. The Systems West GOES/GVAR receiving system is a rather low-end system that generates graphical format products (TIFF) that can be used for visually examining the cloud patterns. The system also includes basic, though important, features including zoom, pan and animation. The UAEAC has developed procedures to convert the TIFF image files to JPEG for internal distribution over UAEAC's INTRANET server pages that can be accessed from all Colombian airports that have suitable communication capabilities (e.g., Microwave or VSAT, see Section 4.6) using AeroCivil's own TCP/IP channels. Unfortunately, the Systems West GOES receiver has lost some of its functionality since the April, 2003, transition from GOES-8 to GOES-12 and only the visible imagery is currently available. During our airport site visits, however, we frequently asked MET observers if they could show us a satellite image and we were never shown any of the imagery from the UAEAC INTRANET server. Typical responses to our request to see some satellite data were to go to the IDEAM web page (where the GOES-12 imagery was not yet being displayed), or go to various public resources available on the internet, such as the Navy Research Laboratory, Monterey.

We understand that UAEAC is planning to acquire a new GOES/GVAR receiving station so as to re-enable the distribution of JPEG format satellite imagery over their INTRANET server.

A more sophisticated satellite receiving station and processing workstation could provide full, direct access to the digital data sets for generating custom multi-spectral products or for giving MET staff the capability to interactively investigate the digital imagery for cloud top temperatures and so on. Another important capability that should be supported by a full-featured satellite work station include a wide variety of remapping options for facilitating data overlays and integration, as well as the capability to export imagery to data integration and analysis workstations used by forecasters and analysts (see Section 4.2.4, below).

High resolution satellite datasets and the capability to display them should be available at every airport that offers MET services. Such data sets could serve as the basis for weather briefings and for giving ATC personnel, dispatchers, and pilots a good situational awareness of weather patterns over all of Colombia and adjacent states.

At present, AeroCivil is conducting a procurement process to acquire a new, upgraded GOES/GVAR receiving system to replace their current Systems West receiving unit. Systems West, it should be pointed out, is now out of business and can't provide upgrades to the existing AeroCivil system.

In addition to AeroCivil's GOES/GVAR receiving station at the Bogotá airport, IDEAM has its own GOES/GVAR and NOAA/HRPT receiving stations at their offices in downtown Bogotá. Both systems are manufactured by Tecnavia, a Swiss company. The IDEAM GOES/GVAR system was upgraded this spring. IDEAM maintains a satellite window on their web page that has not been available since GOES-12 replaced GOES-8 as eastern GOES satellite. The new system from Tecnavia should remedy that situation.

4.2.4 Meteorologist workstations

One of the most noticeable changes in weather forecasting in the past decade is the movement of weather forecast offices away from the traditional walls of weather maps – sometimes hand drawn – to computer workstations with large, high-resolution color displays which are used to visualize the available weather charts, soundings, and satellite imagery needed to make forecasts.

Colombia has already made significant moves in this direction and the OPMET Forecast Center at El Dorado Airport in Bogotá makes good use of computerized workstations (such as the GOES satellite processing and display workstation), general internet access, and computer-based data entry procedures as well as a capable WAFS workstation. The WAFS workstation is the central forecasting tool at the Forecast Center, integrating displays and animations of the various model fields, SIGWX forecasts, and upper wind and temperature charts provided to Colombia from the World Area Forecast Center (WAFC) in Washington D.C. With the upgrades that are underway to the WAFS systems in Colombia, both at IDEAM (downtown Bogotá) and AeroCivil (El Dorado Airport) these capabilities are continuing to improve.

Future enhancements to the OPMET Forecast Center could include additional, networked meteorologist workstations with enhanced capabilities, including capabilities to produce integrated displays of a variety of data sets such as high resolution satellite imagery and locally produced data sets that are not part of the basic suite of products produced by the WAFC. The meteorologist workstations should also include capabilities for plotting and printing radiosondes. Duplication of this sort of advanced meteorological workstation may also be needed for a number of airport sites outside of Bogotá, perhaps customized for presenting weather briefings for pilots and dispatchers.

Currently, WAFS workstation capabilities are limited to IDEAM Headquarters and the OPMET Forecast Center at El Dorado Airport. Airport weather offices throughout Colombia, however, are making considerable use of a variety of lower end computer workstations, primarily standard PC computers with web access. In addition, there are dedicated, single purpose workstations including the display units for various Sutron Automatic Weather Stations. Improvements in weather briefing materials throughout Colombia require reliable network access and improved displays at every Colombian airport weather office. While there are a number of ways to provide enhanced materials for weather briefings, one approach could include web-based systems that can combine access to specialized IDEAM or AeroCivil materials as well as access to the wide variety of publicly available weather resources available on the wide world web.

As discussed in Section 4.6 (below) there is also a need to streamline the data handling of routine airport observations by increased networking of the various data monitoring and product workstations to provide for the efficient transfer of observations and weather products to the various communication portals for data distribution, AFTN in particular.

4.2.5 Weather radars

At present there are no civilian weather radars in Colombia. Colombia does, however, have a full ATC radar network that covers the entire country. This surveillance system was reviewed and discussed in the ISI report (ISI, 2003).

While ATC radars frequently have a "weather channel" that can be used to identify areas of precipitation, the weather products produced by such systems are usually unsatisfactory and can often be misleading. The problem is the inherent result of the differences in radar design needed to optimize a system for aircraft detection as opposed to a system optimized for weather identification and tracking. In particular, the ATC radars have very broad beams in the vertical and are designed to scan rapidly, reducing the sensitivity of the radar for meteorological targets and making it difficult to identify the storm tops. In addition, modern solid state ATC radars are relatively low-powered, magnifying the system's problems in seeing weather echoes and effectively limiting the weather detection capabilities to very short ranges.

In Colombia we understand that the ATC radars' weather channels are either not functioning, or are simply not being used.

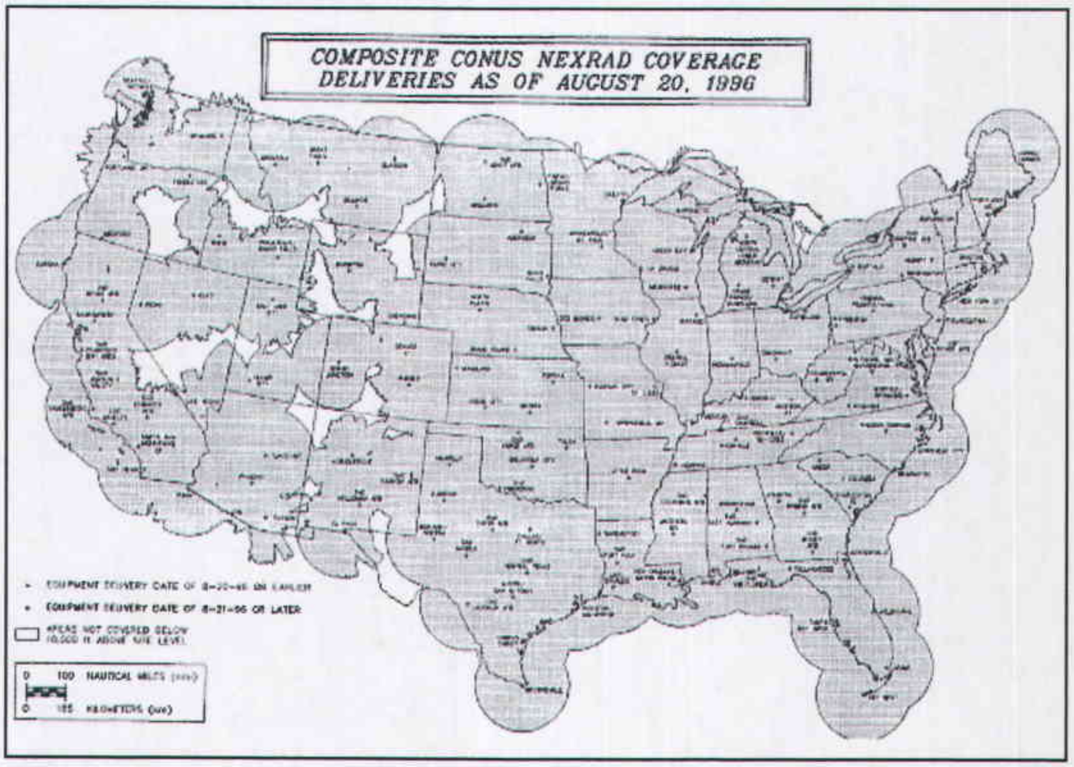
Problems with using broad-beam radars are also exacerbated in hilly terrain, and these problems are evident with the ATC radars in Colombia. For example, the ISI report notes that air traffic controllers rely on the transponder beacon return, rather than the primary skin "paint" (echo), because of problems with anomalous propagation, temperature inversions, and other false targets (e.g., bird flocks and road traffic).

Weather radars can be very useful for real-time forecasting and for issuing convective SIGMETs. In the right environment, high-quality weather radars can be an important component of a modern aviation weather system.

Weather radars can be used to support aviation in two essential ways: first as a network of radars producing composite coverage over broad areas, and second, as individual radars giving coverage over the approach areas of individual airports.

In the 1990's the United States undertook a massive effort to update and expand a network of modern Doppler weather radars (the NEXRAD network) that would give good composite coverage over the entire nation. Figure 4.2 shows an analysis of the NEXRAD network coverage.

From a Colombian perspective, the interesting feature of this coverage map is the more limited coverage over the mountainous areas of the Western US as compared to the total coverage in the Eastern US. The north-south transit across the western US is only slightly larger than the north-south transit across Colombia. Looking at the US coverage map, this suggests that full weather radar coverage over Colombia would require 10-15 weather radars, if not more. In addition, the three chains of the Andes Mountains that cut



source: National Research Council, 1995

Figure 4.14 Composite radar coverage at 10,000 ft over the continental United States.

across Colombia are similar to the Rocky Mountains that run north-south across the American west. As demonstrated in Figure 4.14, large mountains can severely restrict radar coverage areas, making it very difficult to produce good composite coverage over Colombia's major population centers and air routes that follow Colombia's mountain corridor. On the other hand, it would not be difficult to design a limited weather radar network for Colombia that could give good coverage over the relatively flat southeastern portions of the country, although the relatively low levels of air traffic may not justify installation of an expensive radar network over this part of the country.

Weather radars could give good coverage over important terminal areas, such as Bogotá. High resolution radar images could be very useful for local forecasters, for air traffic controllers, and for weather briefings. The easiest way to display the radar data would be on separate, dedicated weather radar display screens, rather than integrating the weather echoes into the existing ATC screens.

While a preliminary assessment is offered above, it is essential that Colombia conduct thorough and complete background feasibility studies, including site selection and analysis, data transmission and networking requirements, maintenance requirements, training and staff requirements, and a comprehensive examination of how the data would be used <u>before</u> starting the procurement process to acquire a weather radar.

4.2.6 Other Colombian weather resources

At present, the aviation weather system in Colombia is exclusively based on the professional staff and observational systems of IDEAM and AeroCivil. There are, of course, other groups and agencies that are concerned with weather and there is a potential to expand the national meteorological observing system and supporting resources through collaborative efforts with these other groups. Collaborative efforts can be difficult and time consuming to negotiate, but can provide a pathway to expanding capabilities that neither agency could pursue on their own.

Some of the groups that may be able to contribute to a general upgrade in Colombian weather observing capabilities include:

(1) Colombian Air Force. During our visit to Bogotá we attended a briefing from meteorological representatives of the Colombian Air Force. They currently make use of observations and forecasts produced by IDEAM and AeroCivil, but don't currently share their own data (though this is the future intention). The Air Force's natural interest and concern about meteorological factors that can impact their operations and affect aircraft safety make them a logical partner to help upgrade Colombian weather observing resources. AeroCivil MET interests should stay in close contact with their Air Force counterparts and try to look for beneficial joint opportunities.

(2) University Meteorology Programs. As we understand it, the Masters Degree program at Universidad Nacional de Colombia, Bogotá, offers the only meteorology

degree program in Colombia. As such, the university should be a valuable resource for training professional meteorological staff and could be a unique partner for applied research on climate, specific meteorological concerns (such as fog and visibility), and studies of instrument calibration and performance. In some cases, focused studies by university students, faculty, and staff members may require funding from AeroCivil, but in other cases access to airport weather information and facilities may be all that would be required. University students and professors are frequently looking for student projects that would acquaint their students with real-world problems and this can be a valuable free resource for operational meteorologists.

During our stay in Bogotá we had a brief meeting with professors from the Universidad Nacional de Colombia and learned that they have groups that are currently involved in studies using mesoscale numerical models (MM5) and lightning. Close collaboration with a University, of course, may also be of great benefit in the development of advanced training or degree programs for IDEAM and AeroCivil staff.

(3) Lightning Measurements by Power Companies. Lightning is the single main cause of transmission line failures and many power companies internationally have invested in lightning detection equipment. In Colombia, there are two separate lightning location systems. One system consisting of 6 sensors was installed by Interconexión Eléctricia S.A. (ISA) and a second, more limited system of 4 sensors operated by a regional power company in Medellín (EEPPM). The ISA system consists of six time of arrival (TOA) systems and a Central Analyzer that receives data from the individual sensors and computes the stoke locations. This network covers a significant portion of main populated areas in central and north-central Colombia (Torres, 2001a and 2001b). With suitable memorandums of agreement, it might be possible for AeroCivil to upgrade, augment, and expand these regional lightning networks into a true national network, with the stroke data shared with the various national and regional power companies.

(4) Research Groups with International Funding. There are many international research programs that are concerned with Central and South American weather and climate. One such study is the Pan American Climate Studies (PACS) Sounding Network (SONET) that evolved in response to the perceived lack of in-situ atmospheric measurements, specifically upper air soundings, over the inter-American region to adequately support climate research studies.

At present SONET is supporting pilot balloon observations at some 21 sites in 8 Latin American countries, including a site in Cartagena run by the Central de Pronósticos Meteorológicos y Oceanográficos. The Cartagena site is apparently intended to fill in for soundings from the inactive Riohacha radiosonde site. In a recent article (Douglas et al., 2004) the SONET investigators also discuss trying to add a pilot balloon station on Colombia's Isla Malpelo.

The PACS-SONET web site is: `http://www.nssl.noaa.gov/projects/pacs/`

4.3 MET data path

Mirroring the MET organization structure, the official data paths are structured in dual, parallel systems. Beyond the official system, however, there is also an unofficial data system based on the internet and publicly available MET information.

4.3.1 IDEAM

IDEAM has developed their own web-based system which MET observers can use to enter individual station observations, such as METARs and radiosonde soundings, into IDEAM's central data base. From there, anyone can access the data (in text format) if they have an internet connection. The IDEAM web page also provides access to WAFS data sets and posts satellite pictures on their web system, although this feature in not currently working (see Section 4.2.3, above).

Observations from stations that are designated as part of the World Meteorological Organization's Global Observing System (WMO/GOS) that are uploaded to the IDEAM data base can transmitted internationally using the WMO's Global Telecommunication System (GTS). Figures 4.15 and 4.16 depict the current North American (including Central America and the Caribbean) and South American regional subsets of the GTS. Colombia is unique in being included in both the Central American Region (because of San Andrés and Providencia Islands) and the South American Region. The Region IV GTS system (North America) is based on 2-way VSAT data links between Washington D.C. and the various national meteorological centers, using the same hardware systems as the 2-way VSAT system that is used for dissemination of the ICAO World Area Forecast System (WAFS) data sets as discussed below. At present, METARs from the nine (9) airports listed in Table 4.4 are transmitted internationally via the WAFS/VSAT data link, as are all Colombian soundings as shown in Table 4.3 (Section 4.2.2, above). With the availability of the Region IV VSAT uplink to Washington, Colombia no longer uses the Region III land line to Maracay, Venezuela.

Table 4.4
International Dissemination of METARs by IDEAM

Symbol	*Airport*	*GTS/WAFS*
SKBO	Bogotá D.C.	X
SKBQ	Barranquilla	X
SKCG	Cartagena	X
SKSP	San Andrés	X
SKLT	Leticia	X
SKCL	Cali	X
SKPE	Pereira	X
SKRG	Rionegro	X
SKBG	Bucaramanga	X

Data provided by AeroCivil

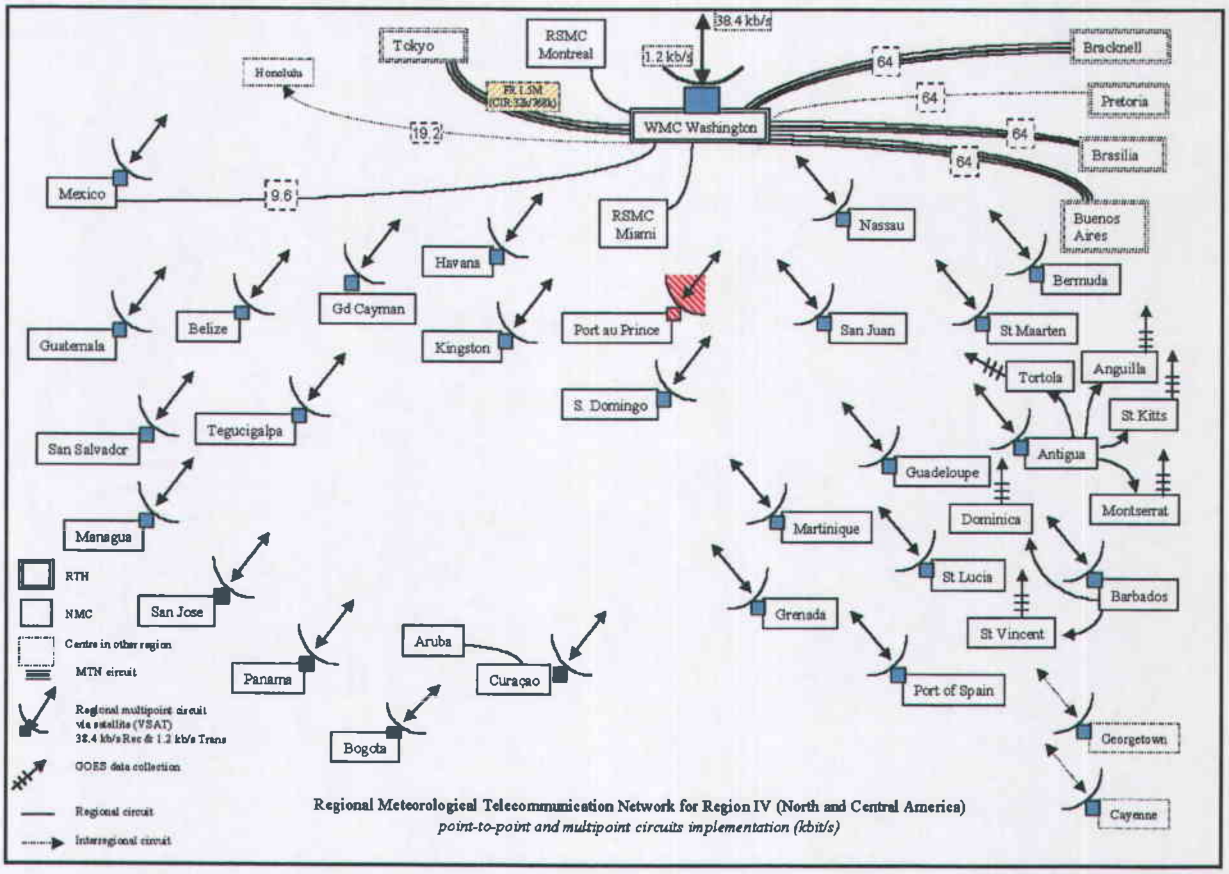


Figure 4.15 World Meteorological Organization (WMO) Global Telecommunication Network (GTS) diagram for Region IV. Note the two-way satellite link between Bogotá and Washington.

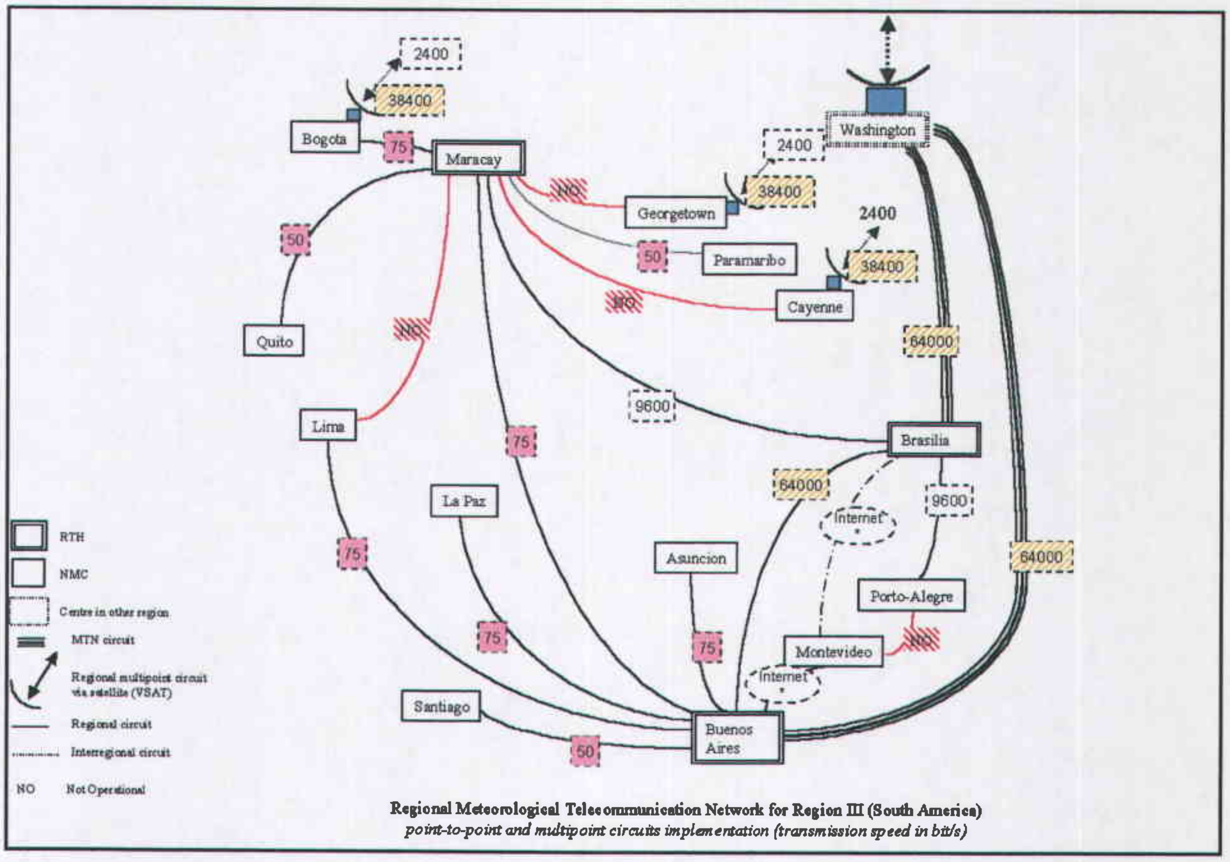


Figure 4.16 World Meteorological Organization (WMO) Global Telecommunication Network (GTS) diagram for Region III. Note dual connection for Bogotá with a satellite link to Washington and a land line connection to Maracay.

In addition to providing for the transmission of observational data sets to the Washington Meteorological Center (WMC), the 2-way WAFS system also allows Colombia to receive gridded forecast model data sets along with copies of wind and temperature charts and significant weather charts that are transmitted from the Washington Wide Area Forecast Center (WAFC) via the WAFS system. Colombia's main WAFS portal is installed at IDEAM Headquarters in downtown Bogotá. A new WAFS system with higher data rates has just begun operation and the data broadcast schedule will be increased to make more meteorological data sets available to Colombia.

4.3.2 AeroCivil

The AeroCivil data distribution system is based on the international AFTN system (Aeronautical Fixed Telecommunication Network). The AFTN is used for a variety of operational aeronautical information, including MET data. The AFTN is a low-bandwidth, text-based system. METARs are generally hand typed into the AFTN system using an AFTN computer console at the airport at which the observation was made. For airports without an AFTN connection, METARs are frequently called in via telephone or radio to a nearby airport with AFTN access or, in some cases, a telephone directly to the Bogotá OPMET Forecast Center. TAFs for seven Colombian airports are entered into the AFTN at the Bogotá OPMET Center. All MET data entered into the Colombian AFTN system are stored in an OPMET Data Bank located at the OPMET Center in Bogotá. Any data stored in the OPMET Data Bank can be retrieved by any Colombian station on the AFTN network within a three-hour window following data entry.

Terminal Area Forecasts (TAFs) are generated for seven of Colombia's International Airports at the OPMET Forecast Center and are copied to IDEAM via FAX (in printed form). Selected observations, and all seven TAFs, are sent on to Regional and International OPMET Data Banks for broad international dissemination. Colombia's central AFTN hub in Bogotá communicates via VSAT connection to centers in Manaus, Maiquetia, Guayaquil, Lima, and Panama. Table 4.5 lists the METARs and TAFs that are routinely transferred to the International OPMET Data Banks.

Table 4.5

International Dissemination of METARs and TAFs via AFTN

Symbol	*Airport*	*TAF*	*METAR*
SKBO	Bogotá D.C.	X	X
SKBQ	Barranquilla	X	X
SKCG	Cartagena	X	X
SKSP	San Andrés	X	X
SKLT	Leticia	X	X
SKCL	Cali	X	X
SKRG	Rionegro	X	X
SKCC	Cúcuta		X

Data provided by AeroCivil

Airports with an AFTN connection can also receive METARs, SIGMETs, and TAFs from airports outside of Colombia by requesting the data from the International OPMET Data Bank.

In addition to information received via the AFTN, AeroCivil's OPMET Center at Bogotá's El Dorado Airport also receives electronic copies of the WAFS data sets received by IDEAM from Washington D.C. These data sets are then displayed on a local meteorology workstation for use by OPMET Center forecasters. The WAFS data sets also include most of the information needed to prepare the International Flight Folders, and the Flight Folder information is subsequently passed on via FAX and internet to other Colombian airports with international flights.

UAEAC is currently acquiring its own two-way WAFS system which will give them independent access to the WAFS data stream.

4.3.3 Informal Communication Channels

With the increasing availability of meteorological information on the web, some MET observers have become quite good at finding weather information. Sometimes these unofficial data sources are preferred to official TAFs. During our airport site visits we watched MET observers demonstrate their ability to access meteorological data from the Weather Channel, Accuweather, the U.S. National Centers for Environmental Prediction (NCEP), the University of Wyoming, and the U.S. Navy Research Laboratory.

4.3.4 International Data Transmissions

While the data handling procedures discussed above include international transmission of METARs, TAFs, and soundings, there often seems to be some difficulty with international data transmission. In particular, the seven TAFs that are prepared for Colombia's International Airports are not always received outside of Colombia.

Based on our discussions with UAEAC and IDEAM (see Tables 4.4 and 4.5), up to ten METARs should currently be transmitted internationally via AFTN and WAFS. Unfortunately not all of these METARs actually make it into the international data bases. Table 4.6, for example, summarizes the actual number of METARs from Colombia that could be retrieved from the GFS system in Taiwan for a 24-hour period ending on 26 May 2004. No reports were received from Pereira, Cúcuta, or Bucaramanga. On the other hand, a full, complete day's worth of hourly reports was received from Bogotá, Barranquilla, Cartagena, and Rionegro. Although Cali operates 24 hours a day, only 20 METARs were made available for international distribution. San Andrés (open from 0600 to 2400) delivered 17 METARs, while Leticia (open from 0600-2000) only delivered 7 METARs.

Table 4.6
Example of hourly METARs available in international system (26 May 2004)

Symbol	*Airport*	*Number of METAR Reports in 24 hours*
SKBO	Bogotá D.C.	24
SKBQ	Barranquilla	24
SKCG	Cartagena	24
SKSP	San Andrés*	17
SKLT	Leticia*	7
SKCL	Cali	20
SKPE	Pereira*	0
SKRG	Rionegro	24
SKCC	Cúcuta*	0
SKBG	Bucaramanga*	0

Figure 4.17 shows a graphical depiction of a similar data enquiry made at the Aviation Weather Center in Kansas City, USA. This illustration shows the METARs available for 12Z (0700 local time) on 28 May 2004. In this case, METARs from five airports are available. San Andrés, which opened at 0600, was able to post a 0700 METAR while Cartagena (on a 24 hour schedule) and Leticia (opening at 0600) were not.

Figure 4.18, generated at the same time, shows a graphical depiction of Colombian radiosonde availability. In this case the only Colombian sounding that made it into international distribution was the one from San Andrés. According to the IDEAM online data archive, however, a 12Z sounding was also collected at Bogotá, but that sounding didn't make it out of the country. This is the same pattern that was observed in an earlier test (see Figure 4.12, Section 4.2.2).

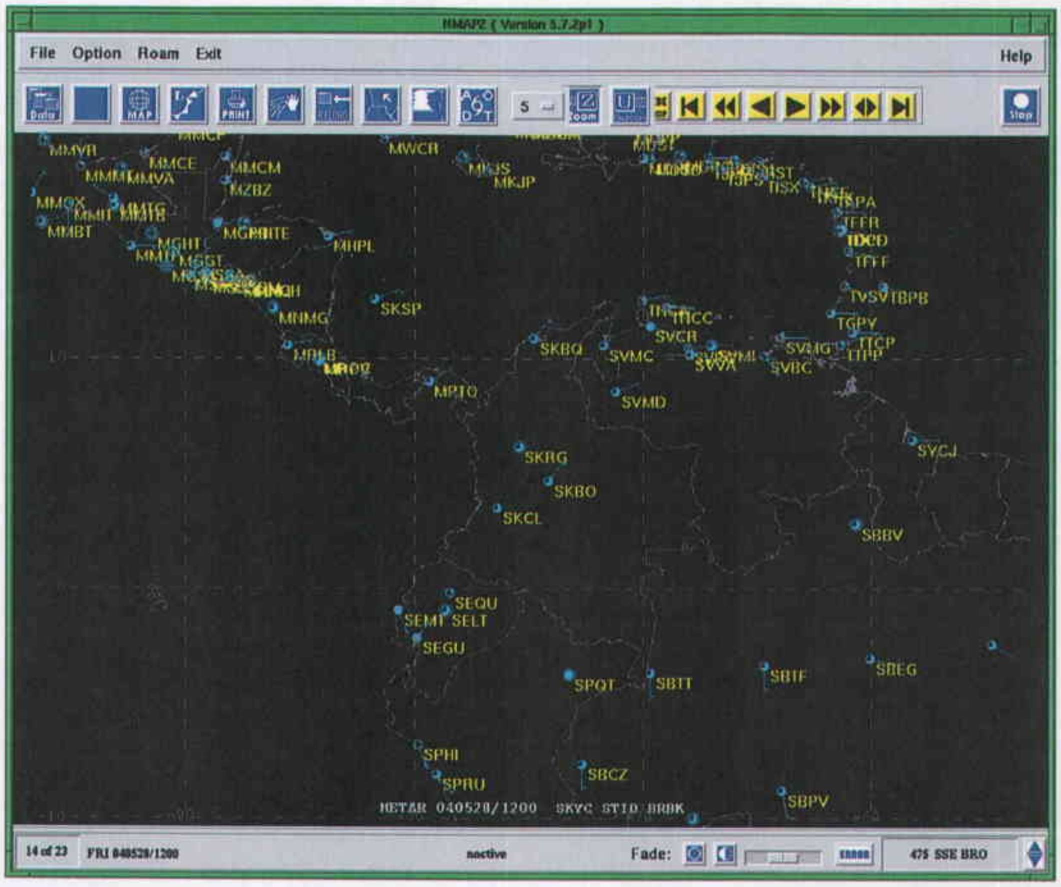


Figure provided by the Aviation Weather Center

Figure 4.17 METAR reports at 12Z, 28 May 2004 showing Colombian METARs available from San Andrés, Barranquilla, Rionegro, Bogotá, and Cali.

While our random spot checks on international data distribution may be misleading, it is clear that Colombia should actively monitor the transmission of their data sets into international distribution systems, verifying routinely which data sets are received and made available to pilots, airlines, dispatchers, and meteorological watch officers in other countries. The efforts that are required to make the observations (METARs) and generate the TAFs are too great to be lost by not following up on their distribution.

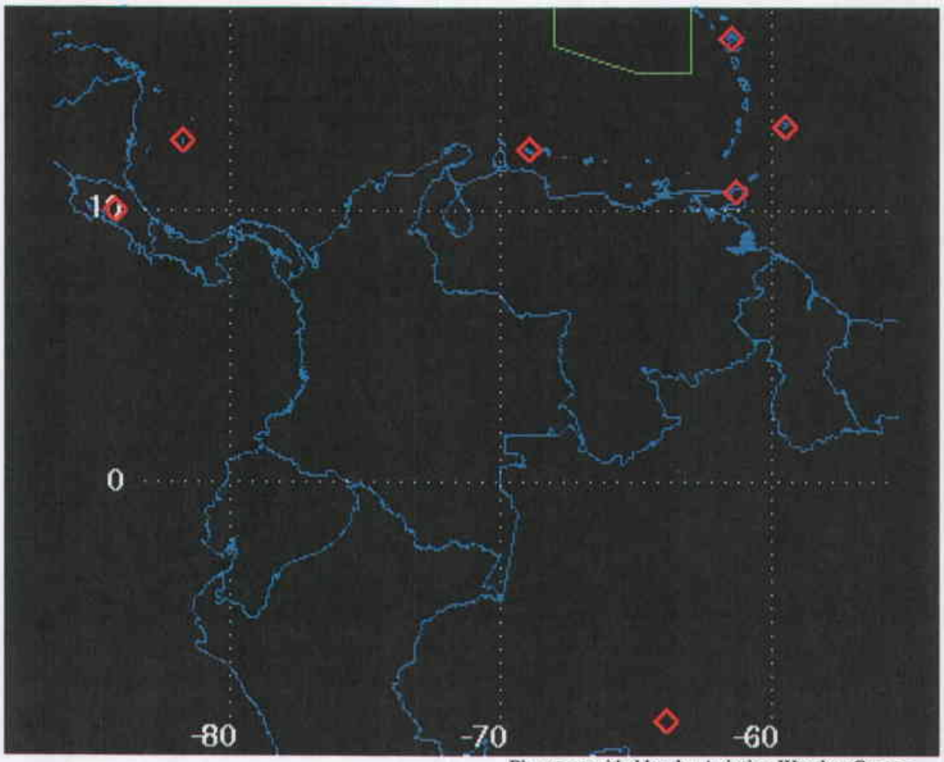


Figure provided by the Aviation Weather Center

Figure 4.18 Soundings available at 12Z on 28 May 2004. Note that the San Andrés sounding is available, while the Bogotá sounding is not.

4.4 Organizational structure

One of the prominent features of the Colombian aeronautical meteorology system is its dependence on shared management and shared responsibility. While AeroCivil is the official ICAO representative and has the responsibility for providing aeronautical meteorological services in Colombia, AeroCivil provides these services through a joint agreement with IDEAM — the national meteorology authority and Colombia's official WMO representative. IDEAM provides most of the meteorological expertise, including the forecasting staff at the El Dorado OPMET center and virtually all of the full time MET observers at Colombian airports. As summarized in Table 4.1, IDEAM staff prepare METARs at 27 of Colombia's 48 controlled airports, with AeroCivil staff preparing METARs at 18 of the smaller airports that don't have full time MET observers.

At present, the Colombian aeronautical meteorology system has a parallel structure with considerable duplication of components. Most noticeably, the surface observing system at Colombian airports consists of a base system of anemometers and altimeters installed in airport control towers (AeroCivil instrumentation) and a MET Garden set up for manual synoptic and climatological observations (IDEAM instrumentation). In recent years IDEAM has added additional automatic sensors in many of their Met Gardens that display real-time measurement in the airport meteorology office while AeroCivil has initiated a program to install similar automatic weather stations at the runway thresholds.

Weather observers make separate reports of their observations to IDEAM and to AeroCivil's AFTN and receive similar training in their own separate training programs.

Each agency separately provides maintenance for their own equipment while communication services and capabilities are AeroCivil's responsibility. IDEAM offices, however, are not totally integrated into the airport communication networks and often depend on commercial dial-up access to the internet.

In this environment it is easy for things to fall into categories of "our equipment" and "their equipment." When instrument problems are noticed, it may not always be clear who to report the problem to, or who should report the problem, or whether there is any money or staff available to perform a repair. It therefore becomes all too easy to say "that's not my job" and just live with a problem rather than moving quickly to get things fixed.

It is not unusual for a country to have separate weather agencies, one within a civil aviation authority and another as the country's main meteorological agency (e.g., for weather forecasting, hydrology, climatology, environmental concerns, and so on). However, in most countries one entity within the country provides the aviation meteorological services. A few examples are: in the United States of American the aviation program is managed by the Federal Aviation Administration (FAA). The FAA then provides funding for the provision of meteorological services to the National Weather Service to solely carry out the program. In Canada, the operational aviation program has been privatized and in turn, the private group known as NAV CANADA has contracted the Canadian National Weather Service to provide all aviation meteorological services with adequate funding provided by NAV CANADA. The country of New Zealand represents a completely different model. In New Zealand, the National Weather Service has been privatized and provides all meteorological services including aviation services on a fee basis. New Zealand also provides aviation meteorological services to other countries on a fee basis. The Republic of Colombia, however, is unusual in that the aviation meteorological services program is split between these two agencies with IDEAM doing things at one airport that AeroCivil does at another.

Part of the problem is connected with the way that IDEAM and AeroCivil are funded. In particular, a major potential revenue source (landing and over-flight fees) appears to be frequently redirected into the general Colombian budget, instead of being fully used to support aviation.

Figure 4.19, below, shows the current number of aviation MET staff broken down by WMO class level provided by IDEAM and AeroCivil. Note that the 19 AeroCivil staff that appear on this chart are primarily MET-trained staff who are preparing METARS at smaller airports as a secondary or collateral job. They are only doing MET part time.

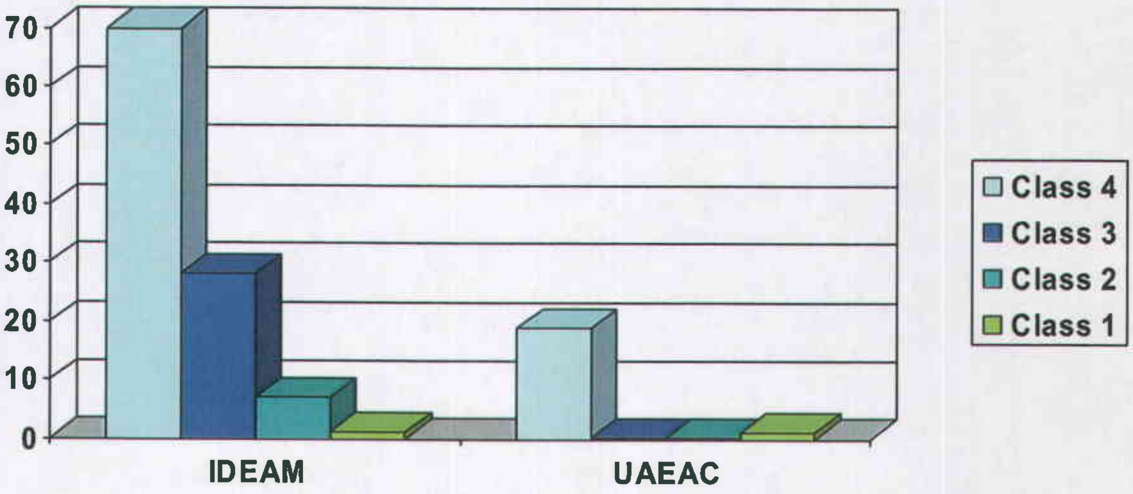


Figure 4.19 Airport MET Staff Provided by IDEAM and UAEAC

The professional staff providing aviation services is mostly limited to Class 4 personnel, i.e., meteorological observers. Observers typically have over ten years of service and have limited opportunities for advancement. This dedicated observer staff is a valuable resource that could play an important role in an expanded aeronautical meteorology system. These existing staff members could, with proper training, assume new, expanded functions, such as enhanced pilot briefings and expansion of the number of airports for which Terminal Aerodrome Forecasts are issued. With a possible expansion in the number of routine TAFS there would likely be a need for more Class 1 and 2 level forecasters. Advanced training of existing, experienced observers is the most obvious source for these possible new positions. Detailed recommendations for a more robust training and advancement program will be featured in the report on Task #3, "Review of the Organizational Structures." In that report the EarthSat team will provide specific prioritized recommendations for possible reorganization of the existing aeronautical meteorology system to meet the requirements for a modern and safe aeronautical program in the Republic of Colombia.

4.5 Structures and facilities for housing equipment and personnel

For meteorological personnel to do a good job, they have to have adequate space and a suitable work environment. As would be expected, the EarthSat team saw a wide variety of office environments during the visits to fifteen Colombian airports. Some of the airports (such as Rionegro, Barranquilla, and Cali) were quite modern and provided excellent working conditions. Other airports (such as Quibdó and Cartagena) offered more basic accommodations. For a large, international airport, Cartagena seems to be somewhat substandard, and we did hear complaints from the local MET staff about their facilities. In virtually every case, however, the MET office spaces that we saw were comparable to other office space at the same airport and one might expect that improvements and upgrades would normally be undertaken as part of a general airport renovation rather than something specifically required for meteorological services.

To the extent that responsibilities and obligations change, however, there may be a natural need to reallocate space to provide for new services. Possible recommendations for expanding meteorological services, such as enhanced pilot briefings, regional forecasting centers, or other new initiatives should trigger an assessment of the associated changes needed in support structures and facilities.

In general, MET office space should be temperature controlled, with air conditioning or heating depending on the season and geographical location. Traditionally, meteorologists' use of computers has been a rationale for requiring air conditioning. With modern computers, however, there is a decreasing requirement for special environmental conditions, although it is still wise to provide temperature and humidity controlled spaces in warm, tropical environments and regularly replace computer fan filters to prevent heat buildups than can shorten a system's expected life.

For briefing pilots and dispatchers, MET spaces should be located adjacent to Aeronautical Information Service (AIS) flight planning areas. For the most part this is how things are set up, but at San Andrés, for example, the MET spaces are located at a remote area of the airport, most likely because of their radiosonde balloon launch responsibilities.

If manual observations are still being done, for example in a traditional MET Garden, the observers should have easy access to the MET Garden area. Priority should be given to providing meteorologists with offices that give them a good view of the airport and surrounding areas, suitable for making observations of current conditions, cloud cover, and visibility. Meteorologists need to be able to see the weather. In some cases, such as Barranquilla, there may be space available in the control tower building (somewhat below the height of the tower cab) that gives the airport meteorologists a particularly fine view of the ambient weather conditions.

Perhaps the most important reports of deficiencies with respect to building and support facilities that we heard concerned power outages and breaks in communication access such as dial-up internet links. In particular, we heard stories of repeated power outages in Villavicencio and loss of phone lines, including dial-up internet access in Pasto. In all cases, airport MET offices should be provided the same backup power and generator support as other essential airport facilities. Depending on the airport power backup capabilities, individual computers may need to be provided with individual, desktop UPS systems.

Communication links available within the MET offices should be integrated with the airport communication systems to provide dependable, secure data exchange and information access.

4.6 Communication and network services

The overall Colombian communication infrastructure supporting aviation was recently reviewed by ISI (2003). In the present report we are more directly concerned with those aspects of the communication system that support meteorological activities.

The AeroCivil communications infrastructure for aviation weather data transmission relies on both satellite and ground-based technologies. The two main systems, VSAT and microwave, provide robust redundant connections between most airports. Recent upgrades to the system, in particular VSAT, have led to well-designed system that is more than adequate for the current operational aviation requirements. The current system, however, was only designed for the minimal weather bandwidths needed to support text-based data transmission.

In recent years, the meteorological staff at Colombia's airports has begun to access additional data sets using an internet web connection. For IDEAM offices at airports, these connections are typically dial-up connections that do not make use of the aforementioned AeroCivil networks. The data rates can vary significantly on dial-up lines. Adequate web connections are becoming increasingly important and should be a standard requirement for airport meteorology offices. In the future, additional modem or phone line upgrades may be required to effectively make use of the meteorological information available through web interfaces. An example of such an application would be a stand-alone, web-based self-briefing weather station.

The microwave system is a UAEAC proprietary telecommunications network. It provides the highest bandwidth links between domestic sites. It serves as the primary link between regional centers and Bogotá. The allocation of bandwidth for different applications is very flexible and allows for reconfiguration and bandwidth assignment. This network seems like the natural choice for potential future aviation weather applications which require higher bandwidth. For example, a potential future expansion of aviation weather forecast offices to the regional centers could add a requirement for more aviation weather specific bandwidth within the microwave system.

The VSAT system provides dedicated line capabilities to all airports equipped with a VSAT antenna. The VSAT system provides the primary channel for aviation weather communications at the smaller airports. The main network control node is in Bogotá with a backup node in Barranquilla. Bandwidth utilization statistics were not available for most of the sites. However, the connectivity level, usually 64 kbps, is more than satisfactory for the current aviation weather network traffic at these sites. Should more bandwidth be required, VSAT bandwidth can be upgraded through acquisition of additional cards and channels.

While the network capacity seems sufficient, there appears to be little standardization in the collection and distribution of aviation weather data. That is, depending on network connectivity, hardware, and maintenance issues, each airport has evolved its own method of reporting and receiving data. The variety of these methods is somewhat astonishing.

In some cases, multi-step voice communication to Bogotá is used instead of the more robust digital data networks. Hardware and software standards would make system maintenance more tractable.

The AFTN system is the primary system for reporting and distributing airport meteorological observations within Colombia. METARs and TAFs, for example, are distributed to other airports and to the OPMET Data Bank in Bogotá through Colombia's AFTN System. AFTN data is transferred in text format and only requires small fractions of the available bandwidth on the VSAT and microwave networks. Access to these reports is critical to Colombia's aviation weather system. Without access to METARs, the airports are essentially blind, meteorologically speaking. As a goal, every airport should have redundant access to the AFTN data stream so they can easily issue METARs and receive weather information from other airports. This is currently not always the case.

The AFTN hardware is a mixture of new and old equipment. The AFTN communication to Bogotá is not TCP/IP-based at many airports. The outdated equipment should be upgraded and the communications protocol should be modernized. Software applications, such as those accompanying the Sutron weather stations in some Colombian airports, provide a more modern and flexible solution.

There is also some concern as to the security of the AFTN system as discussed in the ISI report. It is possible that outsiders could submit incorrect reports into the operational system or that authorized users could submit reports with incorrect location information. In the worst case, the effects of such an erroneous report could be disastrous.

ICAO, in coordination with the World Meteorological Organization (WMO) has established World Area Forecast Centers (WAFC) in London and Washington, D.C., to provide global upper-air wind/temperature and significant weather (SIGWX) forecasts directly to States worldwide through three ICAO satellite broadcasts. WAFS data generated at the Washington WAFC are received via a dedicated VSAT system in Bogotá. The gridded model data and weather charts provided through WAFS are stored locally in Bogotá, where they are used in the generation of TAFs. The Colombian WAFS VSAT system, however, is a 2-way system and is also used to transmit radiosonde and surface weather observations from Colombia to the Washington WAFC.

Based on our airport visits, it appears that the internal coordination of networks at the airports could be improved. The separation of the IDEAM and AeroCivil communications networks, for example, means that observations have to be reported multiple times through different mechanisms. Hopefully, these observations end up being identical. Unfortunately, human-to-human communication links are often used to transfer data between reporting systems. That is, the observations are written down and communicated by voice or paper to AeroCivil personnel who manually enter the data. This can clearly lead to errors in data transmission. Usage of this data by the aviation system is critical and, unfortunately, it is usually AeroCivil that receives the data secondhand. More streamlined and flexible reporting schemes could eliminate this problem.

The network layout at each airport seems to have developed in a very ad hoc manner. Currently, many of the machines within an airport are on separate networks, or not networked at all, and have different means of accessing the internet. Some airports have a Local Area Network (LAN), many others do not. The existing LANs do not interconnect all machines that could take advantage of the network. For example, the IDEAM machines have their own network connections. METAR submission would be more efficient with an improved local network configuration that included the IDEAM machines. Use of a standard LAN configuration could also make maintenance more streamlined. Network expansions to include the AFTN system, however, may require upgrades to the current, aging AFTN system.

The primary links and available bandwidth for Colombian airports are summarized in Table 4.7. This table includes all 47 of Colombia's controlled airports, listed in order of decreasing numbers of annual flight operations. The largest, busiest airports are at the top of the table. In this table, stations that do not have MET internet access or a local AFTN connection are highlighted (shaded). From a meteorology perspective, the most important features of this table are the number of airports where there is no internet access for obtaining web-based weather information, and the number of airports that do not have their own AFTN connections. Eight of the 47 airports do not have an AFTN connection, and eight additional airports only have "receive only" AFTN access. While limited or non-existing AFTN access is most common among smaller airports, one airport (Mariquita) with almost 20,000 flight operations a year does not have its own AFTN data entry port.

Of the 47 Colombian controlled airports, 18 (almost 40%) do not have general internet access for obtaining outside meteorological data. Of the 18 airports where UAEAC staff produce METARs, only 3 airports have internet access for accessing MET information. Of the 27 airports where full-time IDEAM staff provide MET services, only one airport (Barrancabermeja) does not have internet access. In large measure, this organizational difference seems to reflect different organizational policies, but is also clearly influenced by UAEAC's provision of MET services at smaller airports through the use of staff members who have other, non-meteorological, duties to perform.

Table 4.7 Summary of network connections for Colombian airports

AEROPUERTO	METAR	MET Internet Access	Internet Data Rate	AFTN	AFTN Data Rate	V-Sat antenna	V-Sat Data Rate	Microwave Link	Microwave Data Rate
BOGOTA D.C.*	IDEAM	leased	64kbps	CC	9600 bps	7.2 m		✓	E1
MEDELLIN	IDEAM	dial-up		CN	2400 bps			✓	128 kbps
GUAYMARAL	UAEAC	microwave	128 kbps	CN	2400 bps			✓	128 kbps
CALI*	IDEAM	dial-up		SC	9600 bps	3.8 m		✓	512 kbps
RIONEGRO*	IDEAM	dial-up		SC	9600 bps	3.8 m		✓	512 kbps
VILLAVICENCIO*	IDEAM	dial-up		SC	9600 bps	3.8 m		✓	256 kbps
CARTAGENA	IDEAM	dial-up		CN	2400 bps	2.4 m		✓	128 kbps
EL YOPAL	UAEAC	VSAT	64 kbps	CN	1200 bps	2.4 m	64 kbps		
BUCARAMANGA	IDEAM	dial-up		CN	2400 bps			✓	256 kbps
BARRANQUILLA*	IDEAM	dial-up		SC	9600 bps	7.2 m		✓	256 kbps
PEREIRA	IDEAM	dial-up		CN	2400 bps	2.4 m		✓	128 kbps
GIRARDOT	UAEAC	NONE		CN	1200 bps				
IBAGUE	IDEAM	dial-up		CN	2400 bps	**		✓	128 kbps
NEIVA	IDEAM	dial-up		CN	1200 bps	2.4 m	64 kbps		
MARIQUITA	—	NONE		—					
SAN JOSE DEL GUAVIARE	UAEAC	NONE		CN-R	1200 bps	2.4 m			
CUCUTA*	IDEAM	dial-up		SC	9600 bps	3.8 m		✓	256 kbps
QUIBDO	IDEAM	dial-up		?	1200 bps	2.4 m	64 kbps		
SANTA MARTA	IDEAM	dial-up		CN	2400 bps			✓	128 kbps
SAN ANDRES	IDEAM	dial-up		CN	1200 bps	2.4 m	64 kbps		
MONTERIA	IDEAM	dial-up		CN	1200 bps	2.4 m	64 kbps	✓	
CAREPA (Los cedros) APARTADO	IDEAM	dial-up		CN	1200 bps	2.4 m			
ARMENIA	IDEAM	dial-up		CN	2400 bps	**		✓	128 kbps
BARRANCABERMEJA	IDEAM	NONE		CN	2400 bps	**		✓	128 kbps
ARAUCA	IDEAM	dial-up		CN	1200 bps	2.4 m	64 kbps	✓	
MANIZALES	UAEAC	NONE		CN	1200 bps	2.4 m			
PASTO	IDEAM	dial-up		?	1200 bps	2.4 m	64 kbps		
POPAYAN	UAEAC	microwave	128 kbps					✓	128 kbps
PUERTO ASIS	UAEAC	NONE		CN-R	1200 bps	2.4 m			
FLORENCIA	UAEAC	NONE		CN	1200 bps	2.4 m			
VALLEDUPAR	IDEAM	dial-up		CN	1200 bps	2.4 m	64 kbps	✓	
SARAVENA	UAEAC	NONE		CN-R	2400 bps			✓	
TUMACO	UAEAC	NONE		CN-R	1200 bps	2.4 m			
MITU	UAEAC	NONE		?	1200 bps	2.4 m			
COROZAL	—	NONE							
BAHIA SOLANO	UAEAC	NONE							
CARTAGO	UAEAC	NONE						✓	
PROVIDENCIA	IDEAM	dial-up		CN-R	1200 bps	2.4 m			
SAN VICENTE DEL CAGUAN	UAEAC	NONE		CN-R	1200 bps	2,4 m ***			
TAME	UAEAC	NONE		CN	2400 bps			✓	
LETICIA	IDEAM	dial-up		CN	1200 bps	2.4 m	64 kbps		
RIOHACHA	IDEAM	dial-up		CN-R	1200 bps	2.4 m	64 kbps		
IPIALES	IDEAM	dial-up		CN-R	1200 bps	2.4 m			
GUAPI	UAEAC	NONE							
BUENAVENTURA	UAEAC	NONE							
OCANA	UAEAC	NONE		CN	2400 bps			✓	
PUERTO CARRENO	IDEAM	dial-up							

***Regional Center**
****Station to be closed in favor of using the new microwave system.**
*****New station to be installed soon.**

AFTN Code: CC = conmutador central, International Hub
SC = subcentros
CN = conexiones
CN-R = conexiones (receive only)

4.7 Colombian end-user viewpoint

The current aviation meteorology system in Colombia is not being driven in any formal sense by "user requirements," but rather by an attempt to meet the minimum operational and ICAO MET requirements. While international standards and requirements, such as those given by ICAO, are essential for safe and efficient international air routes, they do not necessarily provide for all the meteorological information that is needed for a country to provide a safe and efficient aviation system as discussed previously in Section 3.4. Domestic airports, for example, may need to provide meteorological services at the same level as mandated for international airports and specific airports will often have unique meteorological problems that require sophisticated operational and observing systems that go beyond any international standard.

Perhaps the best way to determine a country's specific aviation support requirements is to monitor and review the problems experienced by the users of the aviation system — particularly airlines, dispatchers, and pilots — and their perceived needs. These user requirements can then be reviewed in terms of international standards and practices, available technologies, and cost.

4.7.1 Pilots, dispatchers, and airlines

As part of its in-country review of Colombia's existing aviation meteorology system, EarthSat met with representatives from a number of Colombian airlines, including Avianca, Satana, Aires, LAS, and AeroRepública. While in Colombia they also met with the Director of Safety for the Asociación Colombiana de Aviadores Civiles (Colombian Association of Air Line Pilots). To put these discussions into a broader context they also met with an experienced air traffic controller from UAEAC to discuss the role of weather from a controller's point of view.

After returning to the U.S. the team also contacted representatives from other international airlines (dispatchers and weather service providers) that fly into Colombia, including American, Delta, United, Federal Express, and Continental.

As a community, pilots and dispatchers are sophisticated in their understanding of weather systems and demanding in their expectations for accuracy. With the increasing availability of high quality weather information over the internet and broadcast on satellite TV, the general aviation community expects to receive high quality, easy to understand weather information. Tools such as high-resolution satellite imagery, color displays and animated graphics are commonplace in the community at large and are expected to be part of an up-to-date weather information system.

Our discussions with airlines, dispatchers, controllers, and pilots were surprisingly uniform. While individual users sometimes had very specific issues of concern, most responses were repeated again and again by every user group we visited. In general, hourly METARs are the central core of the current Colombian aviation weather system and are the first product that the users turn to, but the users want (and need) more.

Surface Observations — METARs. Colombian METARs are generally well regarded, but need to be accurate, consistent, and available. Some users fly into uncontrolled airports (e.g. LAS flights to Puerto Inirida) which have no weather services and would benefit from having a METAR available. It is also relatively common for users to telephone their destinations and ask what the weather is, if a METAR isn't available or if a METAR appears to be wrong. Personal telephone calls to destination airports shouldn't be necessary with an aviation weather system as mature as Colombia's. The "missing" METAR problem, however, most frequently seems to occur for the first flights of the day, when observations aren't yet available from airports that have just opened for service. In this case, weather observation schedules and working hours may need to be adjusted to ensure that all needed weather information is available for flight operations at the time that the airport opens.

Terminal Forecasts — TAFs. The discussions with Colombia airspace users revealed widespread dissatisfaction with the quality of the TAFs. It was claimed they were not always current, and were sometimes completely wrong. International carriers, for example, generally said that they ignored the TAFs entirely and only looked at the METAR reports. Some international carriers obtain their weather forecasts from private commercial sources. In many cases, Colombian airlines are using the current METAR as an indication of what the weather will be when they land. Users generally hoped to see improvements through additional forecaster training and an upgraded national observational system. Most of the users expressed a desire to have TAFs available for every airport in Colombia.

Forecasts for Leticia and San Andrés. Several of the users we talked to emphasized the special importance of TAFs (as well as SIGMETs and en route forecasts) for flights to Leticia and San Andrés. These are Colombia's most distant in-country destinations and the landing conditions cannot necessarily be extrapolated from METAR taken before the flight departs. In both cases, not only is the flight a long one, there are limited landing alternatives. This means that flights to Leticia usually carry enough extra fuel to be able to return to Bogotá so they don't have to divert to Iquitos Airport in Peru, Leticia's main alternate airport. Routinely carrying this much extra fuel is expensive and inefficient. Airlines must have accurate forecasts and frequently updated information for flights to these destinations.

Situational Awareness. Many of the comments we received can be grouped under the heading of improved situational awareness. Users frequently expressed a desire to see more sophisticated information, such as satellite imagery, weather radars, and weather model output displayed graphically. These are the kind of tools that give a broad picture of the weather conditions over the entire country. Such information helps pilots and air traffic controllers react to the current weather situation while at the same time being able to anticipate changing conditions. TAFs, if accurate and prepared for every airport, would help provide this sort of general awareness, but are not as easy to visualize. AIRMETs, AIREPs, and SIGMETs are also essential tools for this kind of situational awareness.

The more sophisticated users we talked to expressed a need for graphical, computer-based displays that could be used as a resource for forecasters, for airlines, and as a weather briefing tool for pilots and dispatchers.

SIGMETs (Significant Meteorological Information). SIGMETs are issued by meteorological watch offices to call attention to en route phenomena that may affect the safety of aircraft operations. SIGMETs are essential for safe air navigation, but are seldom, if ever, issued in Colombia. ICAO regulations mandate that SIGMETs be issued for hazardous weather conditions such as hazardous convection and volcanic ash. As mentioned earlier, SIGMETs are essential to developing a good situational awareness of the weather and are a critical safety and flight planning tool.

Automatic Terminal Information Service (ATIS). Many users that we talked to called for expanded availability of ATIS broadcasts. At present, many of the existing ATIS systems are apparently not being used, or are left in operation with weather information that is out of date. ATIS broadcasts are a valuable resource and can be a source of in-flight weather updates. To be useful, however, ATIS broadcasts must be accurate, timely, and consistent with other current weather information resources.

Additional observing systems. In our discussions, users repeatedly called for enhanced surface observing systems, particularly calling for routine measurements of visibility, RVR, and cloud ceiling. Ceiling and visibility problems are widespread in Colombia's mountain areas, and could be a contributing factor in many of Colombia's most serious aviation accidents. Even some of Colombia's most heavily used airports, such as Medellín, have well known visibility problems but are not equipped with the necessary systems to monitor ceiling and visibility. RVR systems are a basic ICAO requirement for international airports (see Table 3.1), and Colombia is still working at meeting this requirement (see ICAO, 2003, AERMETSG/6). The need for improved observational system for monitoring ceiling and visibility is not just a "paper requirement," but is a clear operational and safety concern for all users of the aviation system: pilots, dispatchers, airlines, and passengers.

Accuracy and consistency of observations and forecasts. One of the most common complaints about Colombia's aviation weather system is inaccurate and inconsistent weather reports and forecasts. While increased accuracy is obviously a long-term goal, there is no justification for disseminating weather information and products that are internally inconsistent. To the extent that this is a real problem and not just users' misperceptions, Colombia should be able to address this issue by making timely updates to reflect changing conditions and through a strict adherence to schedules and procedures to ensure that all products are updated on schedule.

4.7.2 UAEAC internal MET requirements

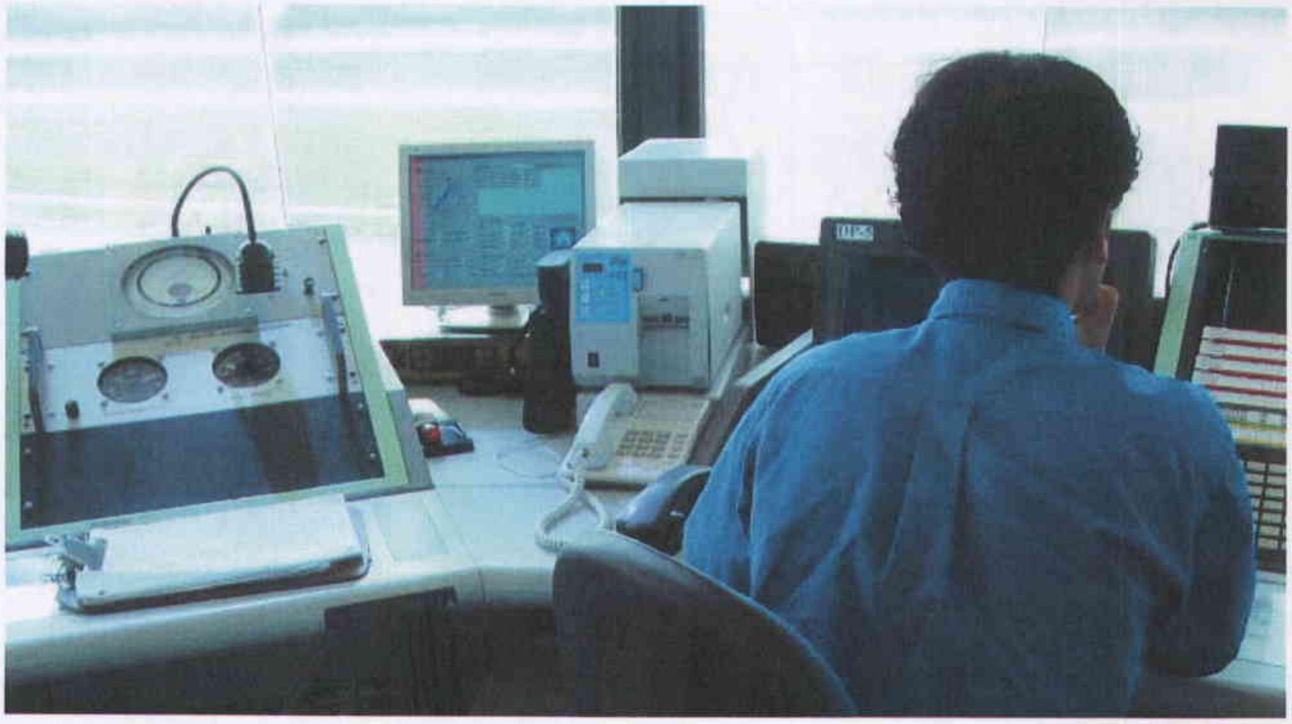
Most discussions of user requirements emphasize "external" users, such as pilots, dispatchers, and airlines. It is equally important, however, to consider UAEAC's "internal" user requirements for meteorological information. In particular, there is a need to examine what weather information air traffic controllers need to know, and how should it be presented to them.

Until recently, there were not many options for how weather information could be displayed. Altimeters and wind systems designed for use in air traffic control towers generally came with large, analogue display dials that were mounted on a wall or control panel. METARs or other weather information were written down on strips of paper and posted where the controller could see them. Figure 4.20 (left) illustrates a conventional tower weather displays.

Baranquilla (Foote) *Baranquilla (Foote)*

Figure 4.20 Conventional dial displays for pressure, wind speed and direction (left) compared with a Sutron computer-screen display (right).

Modern systems, on the other hand, are increasingly making use of computer screens (CRT or LCD) to display weather information. The new AeroCivil Sutron display, for example, is shown in Figure 4.20 (right), and the two systems are further contrasted in Fig. 4.21. For a meteorologist working at a desk, or for a tower supervisor, the computer display screens permit the simultaneous monitoring of many different weather variables. For a working controller, on the other hand, the computer screen may be too complicated and difficult to read at a glance. For efficiency, controllers may need to be provided specialized weather displays that only present the information that the controller needs, in a format that is clear and easy to read. Such a display may be in the form of large-character text-strings, or perhaps in the form of a graphical recreation of the older analogue dials.



Baranquilla (Foote)

Figure 4.21 Meteorological control tower displays, contrasting the conventional dial displays at the left and the computer-based display in the center-rear. The controllers find the conventional display to be much easier to read.

Duplicate displays can also be provided at each controller's position. Multiple, custom designed controller displays are a feature of the (U.S.) FAA's operational Low Level Windshear Alert System (LLWAS)

The important issue here is to include the users of the data, in this case air traffic controllers, in the acquisition and upgrade process to ensure that they get all the weather information they need and to give them an opportunity to evaluate how various proposed instrument displays would impact their work. New systems that aren't user friendly or which are difficult to use often end up unused. When purchasing multiple systems for a number of airports, many vendors will be able to provide custom displays designed to Colombian user specifications at modest additional cost.

Yet another category of internal users are the MET observers themselves. Traditionally the observers have been expected to adapt to outside regulations and end-user requirements, but in an era of automatic weather stations and networked, computer-based communication systems it is important to consider how new systems will support, or hinder, the observers duties. The new Sutron weather stations, for example, include an

ATIS system whose operation interferes with the operators' other duties and therefore is frequently turned off (see Section 4.2.1). This is a good example of the need to include the staff that will use new or upgraded systems in the acquisition process. In some cases different models of a system, or perhaps systems from different vendors, may be a better fit for the Colombian weather system, while in other cases modest changes in the system design or implementation may result in improved performance and efficiency.

4.7.3 Regular meetings with users

The issues discussed above represent a general summary of our findings from a number of brief discussions with Colombian airlines, dispatchers, controllers, and pilots as well as our visits to a number of Colombian airports that offer weather services. In the long term the most important issue that we have identified is the need for UAEAC staff to conduct regular meetings with airlines and pilot associations to review their needs and to get feedback on the services that are currently being provided. While these meetings could be conducted through separate user visits, it may be better to conduct an annual or biannual aviation weather users meeting for all interested users.

One of the findings during our visit was that several airlines purchase meteorological services from foreign, commercial companies. This emphasizes the significance that the airlines place on meteorological services and their unhappiness with the aviation meteorological services provided by IDEAM and UAEAC. A regular users meeting would demonstrate a desire to provide needed services and could build airline support for enhanced Colombian weather systems and services. In this regard, it is important to note that while international providers can supply airlines with a number of aviation products, the fundamental observational systems that form the base for all subsequent weather products are inherently a Colombian obligation.

Several airlines that we visited mentioned that they provide their pilots with regular refresher training courses. UAEAC should explore the possibility of making presentations to pilots during these refresher courses to introduce new weather products and observing systems to the pilots and airlines that will use them.

Internally within UAEAC, there should also be a continual process of evaluation of the adequacy of the weather information and how it can be provided in the most efficient and user-friendly format. Specifically this should include the involvement, to the extent appropriate, of MET observers and ATC staff in the procurement process for new meteorological systems.

4.8 Review of short-term acquisition plans

Colombia has already begun to modernize its aviation weather system through a multi-year acquisition plan. Major new equipment acquisitions are conducted through the Field Procurement Section of ICAO's Technical Cooperation Bureau in Montreal, Canada. For these procurements ICAO prepares the formal technical specifications, solicits proposals, and selects the winning vendor.

Colombia's acquisition plan is described in a planning document was made available to EarthSat in the form of a series of Excel worksheets covering the period from 1998 through 2012. While the specific yearly plans have frequently been delayed, the overall plan seems to be well underway.

One of the most striking features of the plan documentation is the discussion of the rationale for the modernization. In "Formato ID-01, Descripcion del problema o necesidad," there is a blunt assessment that Colombian meteorological information has not been trustworthy because of an inadequate infrastructure for the collection of the basic meteorological observations. IDEAM's aviation weather forecasts are described as unreliable and the lack of accurate and timely meteorological information is considered to have been a contributing factor in a number of aviation accidents.

The general and specific objectives of the acquisition plan are summarized in Formato ID-04.

General Objectives: Expand meteorological observations to airports throughout the country and provide the necessary modern technology for a competitive level of meteorological information through the acquisition of measurement systems that comply with ICAO recommendations.

Specific Objectives: Acquire automatic weather observing stations (AWOS), anemometers, altimeters, RVR, ceilometers, and wind shear detection systems for Colombian airports. Acquire a World Area Forecast System (WAFS) receiver and workstation for receipt of international aviation weather products provided by ICAO's World Area Forecast Center (WAFC) in Washington, D.C. Acquire a receiving system for acquiring and displaying real-time meteorological satellite images.

4.8.1 Acquisition Plan

Most recent updated summary of the proposed acquisitions are presented in "Formato PE-02A: Valoracion del bien y/o servicio." The key elements of the plan are:

- Receiving station for satellite imagery (for Bogotá's El Dorado Airport).
- WAFS receiving station (for Bogotá's El Dorado Airport).
- New Runway Visual Range (RVR) systems for Rionegro, and perhaps for Barranquilla and Bogotá (El Dorado) as well.
- Wind shear detection systems for Pasto, Cúcuta, and Bucaramanga (over a 3 year period).
- Automatic weather observing stations (for virtually all Colombian airports over a period of about 5 years)
- Upgrade or replacement of aging altimeters and wind speed and direction sensors installed in airport control towers (over a period of 5-6 years).

The plan also specifies acquisition of ceilometers and weather radars, but with no specific funding level or date being specified.

Recent Progress. In 2003 twelve Sutron automatic weather observing stations were purchased and installed at Colombian airports. Acquisitions are currently underway, through ICAO, for the WAFS and meteorological satellite (GOES) receiving stations for Bogotá's El Dorado Airport

In follow-up discussions with AeroCivil we learned that, beyond the WAFS and Satellite Receiving Station, the current near-term equipment acquisition plans include:

- 3 RVR systems for Rionegro
- 2 ceilometers, one for Bogotá, one for Cali
- 2 windshear detection systems, one for Pasto and one for Bogotá.
- 5 aeronautical altimeters and 6 anemometers to replace aging control tower systems

These projects all have budget resources that have already been allocated for these acquisitions. Funds are being sought for the purchase of two weather radars in 2005 or 2006. There are also plans to continue the acquisition of additional automatic weather stations, but this will be done through a new procurement, rather than under the contract with Sutron that provided the twelve AWOS systems that were installed in 2003.

4.8.2 Comments on the Acquisition Plan

The RVR and ceilometer acquisitions are very important and should be a high priority. With Colombia's wide-spread problems with ceiling and visibility, additional RVR and ceilometer installations are also needed at other airports. RVR and ceilometers are complimentary systems and, in general, airports with ceiling and visibility concerns should receive both systems. These systems, can either be installed as stand-alone devices, or can be integrated with many vendors' automatic weather stations. If an integrated system is desired, this has to be specified in the procurement documents rather than done as a local adaptation after the system is installed.

Replacing some of AeroCivil's older altimeter and anemometers is certainly a good idea, particularly if they have become unreliable at specific airports. In the long run, however, these systems should be viewed as backup systems for the newer AWOS stations that are being installed.

Material provided to the consultants does not specify what kind of windshear detection systems is being envisioned for Pasto and Bogotá. The main commercial windshear systems are expensive, major acquisitions that are designed to detect convective windshear events associated with microbursts. Such a system seems appropriate for Bogotá. However, the windshear problems at Pasto, Cúcuta, Bucaramanga, and Providencia seem to be terrain induced. Standard commercial windshear systems, such as LLWAS (Low Level Windshear Alert System) are not designed to detect this sort of windshear, and hence are not appropriate. There are a number of other options for improved monitoring of the wind structure around airports that may be more suitable for most of these target airports, such as the installation of additional anemometers, boundary-layer wind profilers, or Doppler lidars. The situation at each airport needs specific, careful study leading to a specific design for each site, following by training on interpretation and use of the system.

5 SUMMARY FINDINGS

Aviation is important to the economic activity in Colombia for a variety of reasons, as discussed in Sec. 1. The aviation system in Colombia is also impacted in important ways by a wide variety of adverse weather phenomena that affect both safety and efficiency of flight operations. These two statements imply that Colombia needs to operate a modern meteorological measurement and forecasting system that is designed to meet the challenges involved. As noted in Sec. 3, there are a number of international agreements in place regarding aeronautical meteorology, to which Colombia is a signatory. These place firm meteorological requirements on UAEAC, as the cognizant civil aviation authority in Colombia. Some of these requirements are currently not being met.

In the last decade or so, a much wider set of aviation weather needs has been developed by the end-user community, as discussed in Sec. 3.4. These present a long list of "softer" requirements (one may refer to them as "highly desirable" capabilities) that are recommended for adoption by civil aviation authorities and the airline industry.

Colombia has developed an extensive aeronautical meteorology data collection network. This system is concerned primarily with surface observations at airports and hourly METAR reports. In fact, the prompt collection and reliable distribution of METARs is a strength of the current Colombian aeronautical MET system. Atmospheric systems are inherently three-dimensional, though, and additional data are needed on the vertical structure, movement, and evolution of weather systems in order to make accurate nowcasts and forecasts of relevant weather. The consultants frequently heard that the quality of the airport forecasts was poor. The relatively limited use of upper-air soundings by forecasters is a weakness. Sounding analysis should be a key factor in forecasting convection and understanding the structure of low clouds and fog.

More generally, Colombia has a critical need to develop an improved situational awareness of the overall meteorological situation at the current time. Forecasters have to be able to monitor the growth and movement of weather systems over all of Colombia and surrounding airspace before they can be expected to forecast the future evolution of these storms and predict their influence on air operations. Transferring this same situational awareness to pilots and dispatchers should be the primary goal of pre-flight briefing materials, and this same understanding of the meteorological situation needs to be passed on to ATC personnel. Without situational awareness, it is difficult or impossible to issue SIGMETs as required by Annex 3 and the CAR/SAM Basic ANP and FASID.

At the present, most weather briefings in the country involve handing dispatchers (and occasionally pilots) strips of paper containing printed METARs for airports along a flight route. These METARs frequently also take the place of forecasts for the destination airport. Developing improved briefing materials should be a priority for Colombia, with an emphasis on graphical products and reliable forecasts.

There needs to be an allocation of resources towards improved forecasts, routine issuance of SIGMETs, and better briefing materials. This will require increased reliance on automatic observing systems to give MET staff time to perform new duties, and the development of a higher-level, professional meteorological staff. One of the principal findings of the 6th Meeting of the CAR/SAM Meteorology Subgroup (AERMETSG/6: ICAO, 2003) was identification of a shortage of MET trained staff in Colombia. The present consultants concur with this finding. The staff upgrades should be based on an improved program of professional education and training that permits existing observers to advance to higher level positions.

Improvements to the aeronautical meteorological system will also require additional equipment upgrades, enhanced communication facilities, and expanded use of networked observing systems and workstations.

5.1 Equipment

5.1.1 General condition and age

Meteorological equipment in Colombia spans a wide range of age and condition. Many of the MET instruments installed in airport control towers have been in place a long time, frequently as long as 25 years. For the most part, however, these older systems seem to be working well, a reflection of their original high quality and installation in the relatively protected environment of the control tower. UAEAC has begun to replace and update some of the control tower MET instrumentation. However, this does not have to be a priority based on age alone. The control tower sensors need to be considered as a backup measurement system to the more modern, remote reporting meteorological stations that are currently being installed. The basic tower instrumentation only need to be replaced if the instruments show clear signs of being defective or become impossible to maintained because replacement parts or regular maintenance supplies are no longer available.

IDEAM's "MET Garden" instrumentation appears to be even older than most of the control tower sensors. For maintaining a reliable climate record, however, it is important to keep using the same basic instrumentation as long as possible. The most common problems we saw with these systems were poor performance of their strip-chart recorders and aging, inaccurate hair hygrometers. The MET Garden instrumentation, however, is not well suited for routine aviation use and the Garden itself is seldom located in an ideal location for monitoring conditions along the runway or at the thresholds.

UAEAC has recently begun a program to install modern, automatic weather stations along airport runways, sometimes at the runway threshold. These systems are discussed in more detail in section 5.1.2 below.

The most obvious problem with the meteorological sensors is the apparent lack of adequate routine maintenance and prompt repair after systems go out of warranty. In some cases, systems that have been installed only a few years ago have been abandoned, taken off the inventory lists, and left to rust in place.

With high quality instruments that are properly maintained, age alone should not be a major problem, so long as the original manufacturer continues to support the sensors and can supply replacement parts.

5.1.2 Adequacy of current equipment

The meteorological instruments installed in the control tower and in the various "MET Garden" sites are not well placed for making routine aerodrome observations. Measurements need to be made in locations that are representative of the airport's runway and the landing thresholds (Annex 3, Paragraphs 4.1.4 and 4.1.9).

The control tower and MET Garden measurement systems, however, are admirable backups for measurement systems specifically designed and installed for airport use. Ultimately all airports providing MET services should install automatic weather stations at locations along the runway boundaries. In the meantime, the control tower weather instruments will often be the only meteorological instruments available at many of Colombia's smaller airports. The basic tower MET systems, however, only include an altimeter, wind speed, and wind direction. There is also a need for at least an approximate measurement of the ambient air temperature to aid pilots in calculating aircraft maximum takeoff weights.

The recent installation of the new Sutron automatic weather stations is a move in the right direction. These systems are well positioned along the runways, frequently at a runway threshold. If the intent, however, is to install only a single weather station at an airport, it is important to consider the location carefully since the measurement will be interpreted as being representative of the aerodrome as a whole. In some cases, additional meteorological stations should be installed.

In reviewing the new Sutron systems we received very good support from the local Colombian representative for Sutron, Apcytel, Ltda. While Apcytel provided us with valuable information, we were not able to get any additional information from Sutron's U.S. headquarters about their system design and the source of their component sensors. We are therefore not able to make an assessment of their systems' overall quality.

The Sutron systems are relatively basic automatic weather stations, only reporting temperature, dew point, pressure, wind direction, and wind speed. It is not clear if the system includes all the internal quality control monitoring and diagnostic tests as are incorporated in systems certified for use in the United States at federally monitored airports. The most important consideration, however, is how reliable the system will be and that is likely to be more directly affected by how well the system is maintained rather than subtle differences in system design or sensor selection.

One of the major Colombian deficiencies identified by the CAR/SAM Meteorology Subgroup at their meeting in 2003 (AERMET/6: ICAO, 2003) was a failure to implement all required RVR systems. In fact, during visits to 15 Colombian airports, we did not identify any fully operational RVR or ceilometer systems. Installation of the required RVR systems should be a high priority. Although not identified by the AERMET/6 report, ICAO standards also require automatic weather stations to be used for CAT II runways, including installation of ceilometers. Although not required, these same system are also recommended for CAT I runways.

Colombia's upper air sounding systems at Bogotá (and to some extent also at Leticia) are troubled by radio interference preventing the measurement of low level winds. In addition, only a limited number of radiosondes are taken due to the cost of the sondes. Upper air soundings are critical for forecasting convective activity and Colombia needs to have reliable 12 Z soundings available from each of the national sounding sites, and should have a goal of also launching a regular 0 Z sounding from Bogotá. Colombia's Vaisala sounding systems apparently need to be updated to solve the radio interference problems experienced at Bogotá, and a full system upgrade should offer significant benefits (see Section 4.2.2). Identifying additional funding resources to permit more frequent radiosonde launches should be a priority.

Currently, not every controlled airport has access to the AFTN for distribution and reception of METARs, SPECIs, and TAFs. The aging AFTN system may well need an upgrade, but this will have to be done in concert with international standards, recommendations, and the general structure of the system. In planning for future upgrades, every controlled airport should be expected to need AFTN access or other ways of sending and receiving OPMET messages through complimentary network communication links.

At the present, most airport MET offices are not fully integrated into the UAEAC airport communication systems and have to access the internet via commercial dial-up lines. Improved access to internet connectivity is likely to become an important issue as additional data sets and large image files are broadcast in support of enhanced pilot briefing systems (see Section 4.6).

5.1.3 Maintenance and calibration

Perhaps the most serious problem uncovered during review of the Colombian aeronautical meteorology system has been the lack of suitable attention to maintenance and sensor calibration. This problem seemed to be recognized by both AeroCivil and IDEAM, and the consultants heard discussion of plans to enhance maintenance activities and to create new organizational entities dedicated to system maintenance. While visiting airports in the field, however, the most common message was that little or no maintenance was provided after the initial system warranty ended. We also saw some examples of missing sensors or displays, some of which had apparently been "cannibalized" to repair equipment at other airports.

It appears that Colombia has a major need for a new or expanded commitment to meteorological sensor calibration and system maintenance. Proper system maintenance, including an adequate schedule of preventive maintenance will ensure the availability of reliable, accurate measurements. This will also translate into longer system lifetimes and lower replacement costs. A comprehensive maintenance program will require a significant budget, but may well save money in the long run.

As a critical aspect of any maintenance initiative, there is a need to establish a calibration facility to make periodic checks of sensor performance. This can be done through the acquisition of a number of portable reference quality sensors that can be used to check sensor performance in their operational environment. A routine schedule of calibration tests should be combined with preventative maintenance activities. Instruments with moving parts, like wind vanes and rotating cup anemometers, usually require the most maintenance, including regular replacement of their bearings on a schedule as recommended by the manufacturer.

In addition to the portable reference quality sensors, there should be a calibration laboratory with more sophisticated reference standards and controlled environment chambers for verifying the accuracy of the portable reference sensors and for extended testing of suspect sensors removed from operational use. This laboratory could be a dedicated facility run by either AeroCivil or IDEAM, or a commercial laboratory that could perform contract services.

Maintenance is a vital part of a meteorological observational system. Annex 3 emphasizes the need for accurate, reliable observations in the context of "quality assurance" (see Annex 3, Paragraphs 2.2.2 to 2.2.4) and explicitly calls attention to the need for calibration and maintenance activities (see Annex 3, Paragraph 4.4).

As a part of a general effort for monitoring data quality, there should also be routine checks to ensure that AFTN and WAFS data submissions are actually reaching their intended international destinations and are available through the GTS and AFTN international OPMET databases (see Annex 3, Paragraph 2.2.5).

In visiting Colombian airports the consultants frequently heard complaints that one sensor or another wasn't working right since it didn't agree with another, independent sensor at the same airport. In most cases, however, the respective sensors were located at different locations, such as on top of the control tower, in the MET Garden, or near the runway. There will usually be real differences between readings made at such locations. Ultimately, each of these sensors should be carefully calibrated to resolve the measurement discrepancies. In the meantime, observers may be able to resolve many of these discrepancies themselves by keeping a careful log of the respective readings to see if there is a constant offset of if the differences depend on the time of day or weather conditions. In many cases measurement discrepancies can be resolved quite easily and so restore confidence in the airport's observational systems.

Observers with a special interest and talent for working directly with the airport weather sensors may be good candidates for advanced training in maintenance and calibration leading up to being assigned to a calibration and maintenance group.

5.1.4 New systems and new capabilities

As part of a general upgrade of the Colombian aeronautical meteorology system there is a need to expand and improve Colombia's meteorological observing systems. Many of the most important potential enhancements fall into three categories. These are discussed only in general terms here, since specific recommendations for enhancements will be considered in a later report.

Situational Awareness:

For aviation meteorology, having "situational awareness" means understanding the current state of the atmosphere. This includes not only the standard surface airport measurements, but also such things as the position and movement of fronts, air mass boundaries, inversions, tropopause height, areas of fog and low cloud, the locations and expected growth of convective systems and thunderstorms, areas of heavy rain, locations of clear air and convectively induced turbulence, in-flight icing, and volcanic ash.

Remote sensing systems are particularly valuable in this regard, including imagery from meteorological satellites, weather radars, and plotted observations from lightning detection networks.

Meteorological satellites can provide 24-hour a day coverage of all of Colombia at a modest cost (see Section 4.2.3). To take full advantage of this resource it may be necessary to acquire relatively high-end receiving systems that permit digital storage and processing of the imagery and the creation of custom products. At its best, satellite data can be presented as full resolution images maps of Colombia and the surrounding airspace with coverage extending to virtually all of North and South America with 1-km visible data (daytime only) and 4-km infrared data (both day and night). The imagery can be presented as zoomed in images centered on Colombia and animated to show cloud motion and growth. Multi-spectral processing can highlight actively growing storms cloud top heights. With local customization, satellite display systems can include detailed overlays showing cities, roads, airports, major flight paths and air traffic control areas, and even positions of aircraft in flight (dependent upon the timely availability of aircraft position information from ATC systems). Making full use of available satellite datasets, particularly from the GOES/GVAR satellite located above the equator at 75° W should be a priority for Colombia. Custom satellite products should be generated at one or more central sites and then be widely distributed to the MET offices of all Colombian airports.

Meteorological radars can monitor the position, growth, and movement of convective storms and precipitation (see Section 4.2.5). High quality weather radars can give good estimates of rain intensity within the radar's field of view and display the position, strength, and height of convective storms. Most modern weather radars include Doppler processing capabilities for monitoring air motions in addition to precipitation intensity. An individual radar can be used to provide coverage over a terminal approach area and, if properly positioned and supplied with suitable processing software, may be able to detect and identify the areas of convective windshear in the airport area. For broader coverage, it is necessary to network a number of radars, sharing data to produce radar mosaics. Weather radars are sophisticated systems and require special training for meteorologists and supporting engineers. Radar data sets are quite large and require high-speed transmission lines to broadcast real-time data.

Lightning detection networks can be used to locate the positions of individual lightning strokes, both cloud-to-ground and in-cloud, to kilometer accuracy using triangulation and time of arrival techniques. Individual sensors transmit their received signals to one or more central sites where area maps and summary displays are generated for distribution to users. Lightning detection systems have been available for a long time, but recent advances in detection technology (principally the enhanced ability to detect in-cloud lightning) has increased their usefulness to operational meteorologists. These systems can now be used to display real-time tracks of lightning activity, effectively identifying the active cores of thunderstorms and giving an indication of the growth and decay. A lightning detection network designed to cover all of Colombia may require 20-25 detectors distributed throughout the country.

Automatic Meteorological Observations:

Colombia has already begun to introduce automatic weather stations at airports. These stations automatically transmit measurements to display screens installed at the airport weather office, control tower, and approach control centers. These systems also have processing software that assists in the preparation of METARs.

The nomenclature used to describe these systems can be confusing. Systems are variously designated by acronyms such as AWS, ASOS, AWOS, AMOS. While the specific nomenclature can be very precise within a given country or from a single vendor, there is no general international agreement on terminology so it is important to examine the capabilities of each system and not just accept similarly named systems as being equivalent.

Using U.S. nomenclature, the FAA certified AWOS (Automated Weather Observing System) designation actually represents a family of systems with eight different configurations:

- AWOS-A Contains only dual-pressure sensors for reporting altimeter settings.
- AWOS-1 Contains sensors for pressure, wind, temperature, and dew point.
- AWOS-2 Contains all AWOS-1 sensors, plus a visibility sensor
- AWOS-3 Contains all AWOS-2 sensors, plus a cloud height sensor
- AWOS-3P Contains all AWOS-3 sensors, plus a precipitation identification sensor.
- AWOS-3T Contains all AWOS-3 sensors, plus a thunderstorm/lightning reporting.
- AWOS-3P/T Contains all AWOS-3P and AWOS-3T sensors.

- AWOS-4 All the AWOS-3 sensors, plus precip. occurrence, type, and accumulation; freezing rain; thunderstorm; and runway surface condition sensors.

Under this nomenclature, the current AeroCivil/Sutron automatic weather stations would be classified as AWOS-1 systems. At many airports in Colombia it would be beneficial to upgrade the automatic weather stations to AWOS-3 class installations, adding visibility and cloud height (ceilometer) measurements that would be processed and displayed using the same integrated workstations.

The FAA's ASOS (Automated Surface Observing System) is similar to the AWOS-4 configuration and is designed to make fully automatic weather reports, such as METARs, without human intervention. ASOS sensors include temperature, dew point, wind, altimeter setting, visibility, sky condition, and precipitation.

Colombia may wish to consider using fully automated surface observing systems, at least on a trial basis. These systems, for example, could be installed at airports that do not offer 24-hour operations, guaranteeing the availability of weather data even during hours of closure. These systems could also be used at small controlled airports that don't have MET staff assigned.

Ceiling and Visibility:

Frequent periods of reduced ceiling and visibility are significant hazards to aviation in Colombia (see Section 1.4.1).

ICAO standards and recommended practices, as well as regional agreements, require installation of RVR and ceilometer systems for international airports and airports with instrument landing systems. In addition to fulfilling its ICAO obligations for RVR and ceilometers at major airports, there are also a number of additional domestic airports that would benefit from the installation of visibility (or RVR) and ceilometer systems. Medellín, in particular, has serious problems with ceiling and visibility limitations and is Colombia's second busiest airport.

As a target, all Colombian automatic weather stations should be upgraded to include ceiling and visibility sensors.

5.1.5 Equipment acquisition process

One of the most important aspects of any development plan that seeks to bring in new observational systems and measurement capabilities is to have a clear vision of the overall enhancement program and how individual sensors will work together and not just consider each procurement as a separate exercise.

The introduction of automatic weather stations at Colombian airports is a good example. The Sutron systems that were installed in 2003 represent a significant improvement over the previous systems that were in use and are, for the first time, installed at good locations for monitoring the airport and runway weather. The systems themselves, however, are relatively modest automatic weather stations that only report temperature, dew point, pressure, and winds. Future enhancements at the same airports may well add ceilometer, visibility, and perhaps even RVR measurement systems. While the additional system enhancements can be installed as separate, stand-alone sensors, it may be more desirable to have the new instruments integrated with the basic weather observations into a single system with single display. If this is not considered as part of the original procurement it may not be feasible to integrate additional sensors as they are acquired in the future.

In this regard, it is particularly important to work with the meteorologists and ATC staff that will be using the new systems to ensure that the system displays, mounting locations, ease of use, and user training are all considered before the procurement process officially starts (see Section 4.7.2). If considered in advance, potential future enhancements and system growth can be included at very little additional cost, while if left until after the initial procurement enhancements and growth may be impossible.

It is important to include system training, maintenance, and calibration requirements in the overall acquisition plan. In general, one shouldn't buy anything until it is known who will use it and how it will be used, as well as having training and maintenance plans already developed and included in the system acquisition budget.

On the technical side, it is critical to understand fully the system being acquired and exactly how it will be used at a particular location. More specifically, it is important to know the critical technical requirements that separate the higher quality systems from those of lower quality. Frequently there isn't too much difference in cost between the top-of-the-line systems and those of lesser quality and the better systems may be a much better value.

For major procurements it will often be necessary to conduct extensive background investigations to become familiar with the technology being acquired and the specific products that are commercially available. These investigations may involve visiting equipment already installed elsewhere, visiting company factories or test stations, and having lengthy discussions with people who have already purchased similar systems. In most cases these trips will involve foreign travel. Project managers for the FAA and meteorologists working for the U.S. National Weather Service will usually be willing to host a visiting delegation to discuss instrument needs and offer advice on how to proceed. In many cases it may also be cost effective to hire an experienced consultant to assist with the preparation of the technical specification or to identify potential systems of interest.

In the end, of course, one desires a meteorological observing system consisting of high-quality instruments that are properly installed and well maintained. Although more expensive in the beginning, these systems will often save money. The alternative of purchasing low-cost systems that need frequent replacement is operationally disruptive and usually more expensive in the long run.

5.2 Operations and procedures

As previously discussed, safe and efficient flight operations require a good situational awareness of current weather conditions, and accurate nowcasts (0 to 2 hours) and forecasts (2 to 24 hours) of adverse weather. At present, this capability is primarily obtained from the products received from the Washington World Area Forecast Center (WAFS), combined with limited local satellite imagery and surface observations. SIGMET and AIREP reports should also provide critical weather information. These aviation-specific reports are essential for aviation safety and efficiency, but are not routinely issued in Colombia. At the CAR/SAM Meteorology Subgroup meeting in 2003 (AERMET/6: ICAO, 2003), missing SIGMET and AIREP reports were identified as "urgent" and "top priority" deficiencies that can have a direct impact on safety.

Colombia needs to issue the required SIGMETs and AIREPs. AIREPs, in particular, should be relatively easy to implement since the formal reporting of written AIREPs is primarily a procedural and operational issue, not requiring any substantial reallocation of resources. Pilots already verbally report turbulence and other hazards to ATC, and these warnings are often transmitted verbally to other planes in the area. The remaining task is to transcribe these verbal reports into written records that can be entered into the AFTN system. The generation of written AIREPs and SIGMETs can be facilitated through the use of computer-based templates for easy report preparation.

For operational efficiency, Colombia should expand the local networking of meteorological workstations so that there isn't a need to manually retype METARs and other reports on multiple systems. Manual retyping is slow and increases the likelihood of introducing errors into the reports. To the extent possible, use of computer templates and automatic checking of outgoing messages to ensure that they are machine readable should be incorporated into routine operations. These systems are needed to support the emerging generation of CNS/ATM systems that will be based on computer monitoring of submitted reports.

Within an expanded system of local networking and data sharing, there needs to be an increased use of meteorological workstations for data integration and forecasting. In particular, these workstations need to incorporate automatic plotting and analysis software suitable for processing Colombian upper-air soundings.

As an important part of submitting METAR and upper air reports into the AFTN and GTS data communication systems, Colombian MET staff should routinely confirm that submitted reports actually get into the international OPMET databanks. There should be a serious effort to ensure that current products, observations, and reports are successfully reaching their intended targets.

As discussed in Section 3.2.1, aerodrome forecasts (TAFs) are required for all eight of Colombia's international airports (CAR/SAM FASID, Table MET 1A), but only seven

TAFs are currently being disseminated (see Table 4.1, this report). Cúcuta is the only international Colombian airport for which the Bogotá MWO does not issue a TAF.

As a goal, Colombia should work towards having forecasts (TAFs) for every controlled airport. Such an expansion in the number of forecasts may require the decentralization of the aeronautical forecasting to regional centers or to local airports where the experience of the airport meteorologists regarding local weather could be an advantage.

As a key component of the forecast program, AeroCivil and IDEAM should initiate a comprehensive program of forecast verification as a tool for improving forecasts and as a way to increase confidence in the forecast products.

At present, Colombia has not established effective two-way communication with the Washington Volcanic Ash Advisory Center (VAAC). Because of the extreme time sensitivity for issuing notices of volcanic eruptions, communication with the Washington VAAC requires special procedures, including authorizations for direct long-distance and telephone calls and FAX transmissions. As soon as there is any evidence of an imminent eruption or early reports of an actual eruption the Bogotá MWO is required to issue a SIGMET announcing the potential danger. After issuing the SIGMET, the MWO should follow up with a direct phone call to the Washington VAAC, a FAX, or a direct e-mail message notifying them of the eruption or potential eruption. After being notified, the Washington VAAC will monitor the volcano and issue its own advisory with more specific information about the hazard. After receiving the volcanic ash advisory or other direct contacts from the Washington VAAC, the Bogotá MWO will issue a second, more detailed SIGMET, if required. Volcanic ash SIGMETs are always issued by the MWO and not by the VAAC. To ensure that the MWO is able to communicate with the Washington VAAC as required, Bogotá should confirm that the Washington VAAC has current contact information for the MWO (including voice phone and FAX numbers) and conduct yearly communication tests with the VAAC.

5.3 Services provided to airspace users

As discussed in Section 4.7, users of the Colombian aviation meteorology system have many needs and desires that are not yet being met. Some of the more specific issues include the following:

(1) A number of airlines have complained that their early flights are often delayed because necessary METARs are not available to support flights scheduled to depart immediately after an airport opens. This is apparently in direct violation of the CAR/SAM Basic Air Navigation Plan (ANP), Chapter 6, Paragraph 8 and may require modifying the hours for MET services so as to start before the airport opens, or the installation of fully automatic observing systems to generate the necessary observations during hours of closure.

"At aerodromes with limited hours of operation, routine reports and forecasts should be issued sufficiently early to meet pre-flight and in-flight planning

requirements for flights due to arrive at the aerodrome concerned as soon as it is opened for use. Furthermore, aerodrome forecasts should be issued with adequate periods of validity so that, collectively, they cover the entire period during which the aerodrome is open for use." *(CAR/SAM ANP)*

(2) There is a need for enhanced weather briefings for pilots and dispatchers, particularly with the use of graphical weather products.

(3) METARs should be routinely available at all controlled airports. Additional METARs may also be needed at selected uncontrolled airports.

(4) Forecasts are needed for domestic airports as well as for Colombia's international airports. As a goal, TAFs should be available for every controlled airport. As indicated earlier, the quality of the TAFs needs to be improved.

5.4 Personnel and training

The vast majority of the meteorological staff working at Colombian airport meteorological offices and the Bogotá Meteorological Watch Office are classified as observers, many of whom have performed the same job for 15-20 years (see Figure 4.19). These observers have shown great loyalty and dedication in staying with their jobs this long even without opportunities for training or professional advancement. The consultants feel that these staff members represent an untapped resource that could be used to increase the number of more highly trained MET staff. With the eventual introduction of advanced observational systems and improved meteorological briefing materials, it will become increasingly important to develop personnel to fill more high-level meteorologist positions. The most efficient way to fill these positions is through advanced training of existing staff members.

The introduction of automatic weather observing stations at Colombian airport should eventually reduce the time required to prepare and distribute METARs and other routine observational chores that take up most of the observers' work day. With additional training, the observers could be able to provide enhanced briefing services and assist with the preparation of TAFs for additional airports, while limiting the need to hire more staff.

In additional to the standard courses for advancement to higher WMO classifications, there may be a particular need for special training in the areas of sounding analysis and prediction of convective activity. The prevalence of airports with frequent ceiling and visibility problems suggests that special training in predicting the onset and clearing of fog and low cloud would be a great benefit to the Colombian meteorological system. As new equipment and facilities become available, there will need to be special training courses for the users of the new resources, well beyond a cursory training of a limited number of designated staff.

The training program should make full use of CAR/SAM technical cooperation regional projects as well as taking advantage of the full range of WMO training opportunities.

Additional specialized training may require an enhanced training budget within UAEAC (or IDEAM) to support customized training programs that would be offered to aviation meteorologists.

At the highest level, senior meteorologists should be encouraged to seek advanced university degrees either in Colombia or outside the country. Such training, perhaps assisted by government financial assistance, could be used to develop advanced capabilities in specialized applications such as radar meteorology, satellite meteorology, or numerical modeling.

One way to ensure that training is focused on actual day-to-day operational needs would be to bring in outside consultants, perhaps recently retired senior meteorologists from the CAR/SAM region or Spanish-speaking meteorologists from Europe or the US, to act as resident mentors, working alongside Colombian forecasters and analysts as they do their normal daily activities.

5.5 Organization

As discussed in Section 4.4, the existing organizational structure of the aeronautical meteorological system in Colombia involves parallel systems with considerable duplication of components and overlapping responsibilities. While organizational issues will be addressed in a later phase of this study, it is clear that there needs to be a thorough examination of the options for streamlining the organizational structure and improving efficiency. Changes to the agreement between UAEAC and IDEAM may be necessary based on the current realities. In the end there needs to be a clear structure, with clear responsibilities. The current system seems to encourage split obligations and affiliations. IDEAM observers, for example, tend to use IDEAM measurements systems to generate METARs rather than the better positioned AeroCivil sensors near the runway.

Before entering into serious consideration of reorganization, it will be necessary for AeroCivil and IDEAM to conduct a careful review of their respective responsibilities and obligations for the airport meteorological stations. AeroCivil's obligations are solely directed to meteorological support for aviation, as summarized in Table 3.1 of this report. Many of the airport weather stations, however, are also used as synoptic stations in support of the WMO's World Weather Watch and Regional Basic Synoptic Network (RBSN) as well as serving as climate stations as part of the WMO's Regional Basic Climate Network (RBCN) and Global Climate Observing System (GCOS). The long history of IDEAM measurements from airport sites is reflected in the presence of the "MET Garden" synoptic stations at Colombian airports. These synoptic stations are not well suited for aviation support and were designed for manual synoptic observations. It is not clear to what extent IDEAM's national and international responsibilities require them to maintain the MET Garden synoptic stations and separate reports. In some cases, for example, it may be acceptable to substitute standard METAR reports for the SYNOP and other special reports referenced in Tables 3.2 and 3.3. The GCOS surface network (GSN) stations are providing long term climate records for national and international use and probably need to be maintained. Even if these observations could be switched over to new, automatic observing stations along the runway, there would still need to be a period of at least a year with dual measurements to establish any systematic bias in the two reporting streams and allow long term climate investigations to adjust for a change in sensor technology and location.

As part of this review of national and international data reporting requirements, AeroCivil and IDEAM should carefully review the relevant ICAO and WMO documents for consistency and accuracy. In reviewing these documents for this report we discovered a number of what appear to be unrealistic commitments, observing stations that may no longer be in service, and internal inconsistencies. Updating the formal ICAO and WMO publications, however, should wait until a clear plan for future Colombian observations has been agreed upon.

Ultimately AeroCivil, as the national civil aviation authority and ICAO representative, has the responsibility to provide meteorological services for Colombian airports. These services, however, don't have to be provided by UAEAC employees. Options for providing MET services could involve AeroCivil contracting with a separate service provider with clear contractual obligations for service and cost reimbursement. This service provider could be IDEAM or a private contractor. Meteorological sensor systems could be supplied by AeroCivil, with maintenance and calibration services maintained within AeroCivil or contracted out. Alternative arrangements could involve a cooperative agreement between IDEAM and AeroCivil, as in place now, or a total transfer of aviation meteorological support to IDEAM.

As the Colombian national meteorological authority and WMO representative, IDEAM has the obligation to continue to provide weather observations in support of the World Weather Watch, the Global Climate Observing System, and a variety of Colombian users of meteorological, climate, and hydrological information. These obligations may involve maintaining their own observing stations at a number of airports. These obligations, however, don't necessarily have to be provided by IDEAM employees. Options for continued observations from these sites could include IDEAM support for observations by AeroCivil, volunteer observers, or private contractors. The existing synoptic measurement systems, principally those in the "Met Gardens" could continue to be maintained by IDEAM staff or contracted out. An alternative arrangements, of course, could involve a cooperative agreement between AeroCivil and IDEAM, as is currently in place, or the use of standard METARs to fulfill IDEAM's requirements for synoptic and climate observations.

Changing the organizational structure can't compensate for inadequate funding and limited resources, but may minimize duplicate efforts and remove some administrative obstacles to efficient operations.

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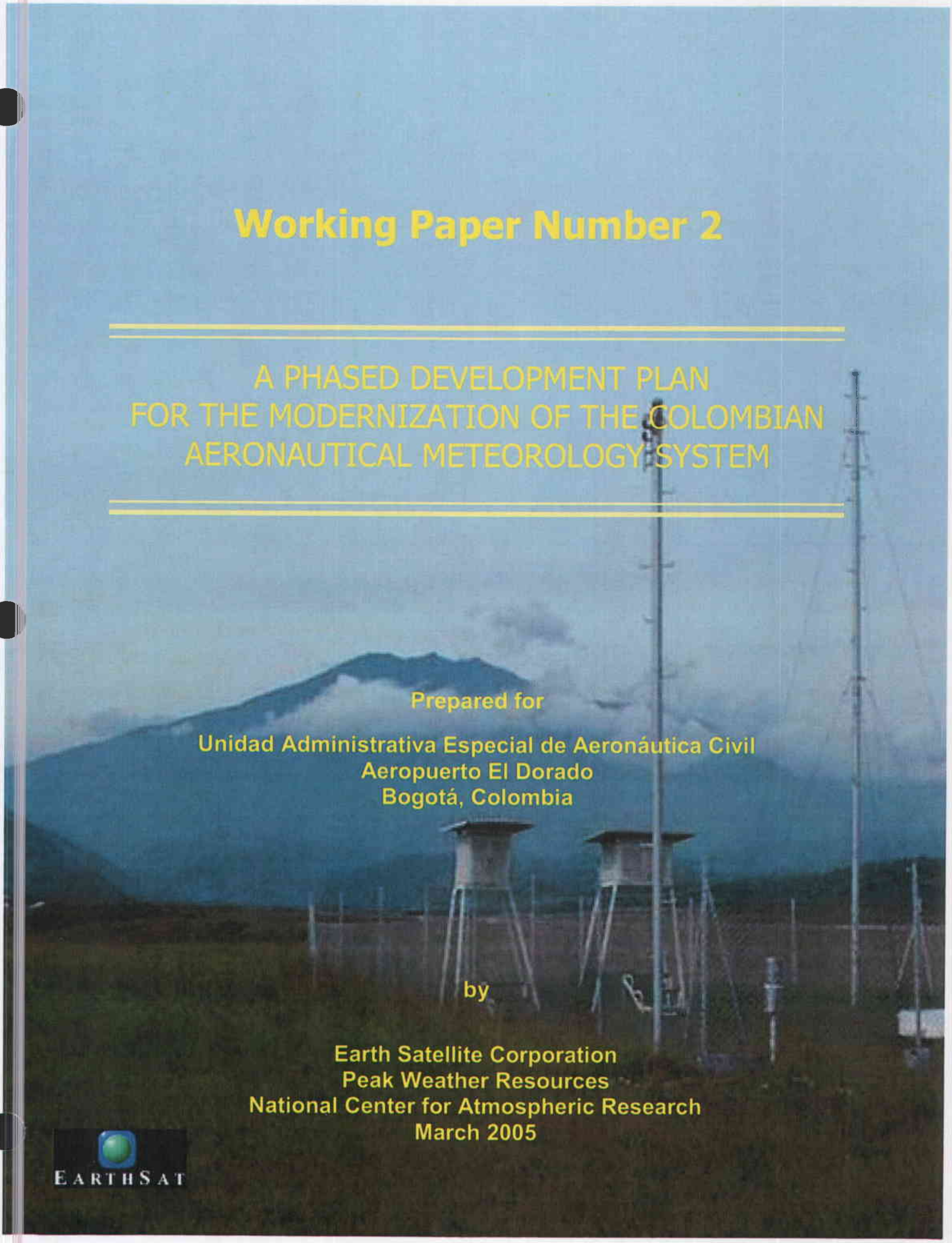

Working Paper Number 2

A PHASED DEVELOPMENT PLAN FOR THE MODERNIZATION OF THE COLOMBIAN AERONAUTICAL METEOROLOGY SYSTEM

Prepared for

Unidad Administrativa Especial de Aeronáutica Civil
Aeropuerto El Dorado
Bogotá, Colombia

by

Earth Satellite Corporation
Peak Weather Resources
National Center for Atmospheric Research
March 2005

EARTHSAT

Table of Contents

1 Modernization and Upgrading of the Colombian Aeronautical Meteorology System for Safety and Efficiency

The contract language for the current work states that "The Consultant will develop options to modernize the existing Colombian aeronautical meteorology system to provide an efficient, safe, and reliable system that accommodates transitions to CNS/ATM technologies and systems. The Consultant will also assess the related cost for implementation of the various options, systems and equipment identified." These options and recommendations are to be developed in consultation with UAEAC (Unidad Administrativa Especial de Aeronáutica Civil) into a phased development plan that will be presented as the second working paper for this consultancy.

1.1 Meetings and presentations.

In Working Paper Number 1, EarthSat reviewed the current state of the Colombian aeronautical meteorology system. The findings of that first report were presented to UAEAC on 17 August 2004 at UAEAC Headquarters at Bogotá's El Dorado airport by Dr. David Johnson (NCAR) and Mr. Ron Price (EarthSat). In conjunction with the formal presentation of the first working paper we also discussed some of the likely recommendations for upgrading the Colombian aeronautical meteorology system.

On 18 August 2004, Dr. Johnson presented a series of three informational lectures. His lectures were titled:

- *Weather Radar Theory and Systems*
- *Windshear and Turbulence*
- *Lightning Structure and Lightning Detection Networks*

Following Dr. Johnson's presentations, EarthSat consultants Prof. Vilma Castro, Luis Fernando Alvarado, and Gabriela Mora subsequently presented formal training classes in two subject areas:

- *Satellite Meteorology (4 days)*
- *Numerical Weather Prediction (2 days).*

1.2 General approach.

The plan for upgrading Colombia's aeronautical meteorology system must be considered as a part of the overall Colombian national meteorological system. In general, there is no clear line separating observing systems and support structures designed for aviation meteorology and those designed for general meteorological applications. In our working paper we will focus on the Colombian aeronautical meteorology system under the terms of the EarthSat agreement with UAEAC to provide aeronautical meteorology system technical assistance to the government of Colombia. Eventually these recommendations will need to be incorporated into a joint vision with IDEAM (Instituto de Hidrología, Meteorología y Estudios Ambientales), Colombia's primary civilian weather agency. At the most basic level, of course, all Colombian weather agencies need to share their observational data and weather products.

International Civil Aviation Organization (ICAO) and World Meteorological Organization (WMO) responsibilities for Colombian meteorology were reviewed in our Working Paper Number 1. UAEAC is the designated Colombian meteorological authority for aeronautical meteorology and is the national representative to ICAO. IDEAM is the designated national representative to the WMO and is responsible for carrying out the WWW observations and reports.

UAEAC and IDEAM are currently operating under a joint interagency agreement to provide aviation weather services for Colombia. While there are many different models of how to provide aeronautical meteorological services, many of which involve shared responsibilities, the current situation in Colombia seems to be problematic and may need to be revised. In a separate report (Working Paper Number 3), EarthSat will review the current organizational and management of structure of UAEAC and IDEAM and make recommendations for improving the efficient delivery of aeronautical meteorological services. The current report (Working Paper Number 2) will emphasize equipment, facilities, and operational capabilities.

In general, EarthSat recommends that UAEAC assume the responsibility for providing and maintaining all the basic airport observing systems, including meteorological observations and measurements, so that there can be a clear sense of responsibility and in order to simplify the full integration of the meteorological systems into the airport infrastructure, communication links, and operational support. UAEAC should also be directly responsible for the meteorological observers who work with the airport observing systems. If implemented, this would mean transferring a considerable number of MET observers from IDEAM to AeroCivil. Non-aviation meteorological responsibilities, including general synoptic, climatological, and hydrological observations, reporting, and forecasts should be the sole responsibility of IDEAM.

Specific ICAO standards and recommended meteorological practices are discussed in Annex 3 to the Convention on International civil Aviation (ICAO, 14th Edition, 2001). Strictly speaking, the ICAO meteorological standards only apply to an agreed list of designated international airports and do not necessarily apply to domestic airports. This is, however, primarily an administrative and jurisdictional distinction that is intended to limit an international agency from dictating a country's internal policies and procedures and does not mean that domestic airports do not need the same level of meteorological support as international airports. <u>To the extent possible, all domestic controlled airports should follow ICAO standards</u>.

The new observing systems and meteorological products recommended in this working paper will significantly increase the responsibilities of UAEAC. At the same time, we feel that increased use of automated observing systems and networked communication links will allow the new responsibilities and new tasks to be accomplished without having to increase the total number of MET staff. This change will require a major commitment in education and training to prepare the existing MET staff for their expanded responsibilities and a general upgrade of the MET staff to higher level classifications.

2 Critical Deficiencies in the Current System

In Working Paper Number 1, EarthSat reviewed the current Colombian aeronautical meteorology system and identified a number of deficiencies. In general, these deficiencies fall into two broad categories. On one hand there are deficiencies that reflect a failure to meet specific international ICAO standards. A number of these deficiencies were also highlighted in the report of the Sixth Meeting of the CAR/SAM Aeronautical Meteorology Subgroup that was held in Brasilia, Brazil (ICAO, 2003). These deficiencies should be addressed as soon as possible. The second category of deficiencies is more subtle and reflects a failure to meet the meteorological needs of the aviation community through the provision of enhanced safety and efficiency by providing improved weather services. In this case the ultimate goal is to provide high quality meteorological services that go beyond a set of minimum standards.

While it is important to try to remedy deficiencies as rapidly as possible, it is also important to have a clear view of the overall direction of future weather system upgrades to ensure that deficiencies are addressed in a ways that are consistent with Colombia's long term plans and which support the transition to CNS/ATM technologies and systems.

The following subsections review a number of the more important deficiencies identified in Working Paper Number 1. The first four reflect deficiencies identified in the CAR/SAM aeronautical meteorology subgroup meeting and the final three reflect broader areas where systematic improvements are needed.

2.1 Inadequate numbers of qualified MET staff.

The introduction of new technologies and products, coupled with a desired expansion of meteorological services – such as increasing the number of airports for which terminal area forecasts (TAFs) are issued – will require more MET staff being qualified to higher classification levels. Increasing the number of qualified MET staff will require improving the educational and training opportunities of current MET staff and working with Colombian universities to expand their meteorological training programs. In the long run it is equally important that UAEAC and IDEAM offer attractive career opportunities and salaries that will attract and maintain high quality personnel.

2.2 Colombia does not issue AIREPs or SIGMETs.

Special AIREPs and SIGMETs need to be formally entered into the AFTN system so all aircraft can be made aware of possible hazards to safe operation. Formal submission of AIREPs requires carefully constructed and practiced procedures that may be difficult to implement. Issuing SIGMETs requires forecasters to be able to identify the location and strength of weather hazards, which is difficult with the currently available observations. Improving the situation will require careful adherence to procedures and upgraded observational systems.

2.3 RVR and ceilometer systems are not installed at all international airports and airports with ILS systems.

RVR and ceilometers are required or recommended at all international airports and for all instrument landing system (ILS) runways. RVR systems, however, are expensive and are not yet installed at all the required airports. This is primarily a funding and maintenance issue.

2.4 Problems with the OPMET data exchange.

While the CAR/SAM meteorology subgroup report does not identify specific problems with the OPMET exchange, it is clear that there are frequent examples of missing METARs, TAFs, and typographical errors in manually entered reports. These problems will become increasingly important in future automated international systems that depend on computers to decode and process meteorological data and forecasts.

2.5 Inadequate maintenance of installed systems.

Many of Colombia's meteorological observing systems appear to be poorly maintained and unreliable. Preventative maintenance and routine calibration of instruments will provide accurate, reliable observations. High-quality meteorological systems that are well maintained should provide many years of service and save money in the long run by delaying the need for routine replacement.

2.6 Lack of systems to give forecasters a good situational awareness of Colombian weather.

At present, the Colombian aeronautical meteorology system is primarily based on hourly METARs in text format. Relatively little use of made of satellite imagery and forecasters have limited tools to help them develop a situational awareness of the location and evolution of Colombian weather systems. Improvements will require better use of satellite data sets, perhaps augmented by weather radars or lightning detection systems. It is equally important to transition to graphically based products and displays using integrated forecasters' workstations.

2.7 Better products and technologies are needed for briefing pilots.

Just as forecasts are largely based on METARs in text format, domestic pilot briefing is similarly grounded in METARs with TAFs only being available for a limited number of international airports. The international flight folder program through the WAFS system provides somewhat better briefing materials for international flights. Modern, graphical briefing materials on color workstations are more effective at depicting critical weather information and identifying potential weather hazards than text reports and give better support to pilots and air traffic personnel.

3 Major Goals and Targets

Before presenting a list of specific recommendations for meteorological system enhancements, we would like to put the recommendations in perspective by outlining some of the major goals and targets of our proposed modernization plan.

3.1 Collect and report hourly METARs from all controlled airports.

At present, METARs are reported at 45 of Colombia's 48 controlled airports*, but most reports are not distributed outside of the country. One of the principal goals of future CNS/ATN technologies is to transmit more meteorological data to a broader set of international users. In Colombia, the WAFS uplink to Washington represents a reliable, high band-width transmission capability that is suitable for distributing a fuller set of meteorological observations, including METARs from all controlled airports.

Many of the Colombian airports that do report METARs have limited hours of operation, with the MET observations being discontinued after the airport closes. Meteorological analysis, on the other hand, is a round-the-clock activity and would benefit from routine, hourly observations from all controlled airports. With a transition to a nation-wide system of graphical analysis and display of meteorological data there will be additional benefit to maintaining a full set of 24-hour observations in support of improved airdrome forecasts and better pre-flight briefing materials.

Colombia has one private, controlled airport that has recently upgraded its meteorological systems with a fully automated weather reporting system that is capable of providing round-the-clock automatically generated METARs. If adequate communication links permit, the METARs from this airport at El Cerrejón (El Mina) should be ingested into the national meteorological system and shared internationally.

We recommend moving towards the installation of automated meteorological observing stations that can generate METAR reports around the clock, even during non-operational hours while the airport is closed (see Section 4.1)†. These new, high-end automated weather stations might initially be introduced at smaller airports with limited hours of operation or at airports for which no full-time MET staff are assigned. Eventually, these automated weather observing stations should expand to all controlled airports, giving Colombia a reliable, uniform, full-time meteorological observing system.

In some cases, it would also be beneficial to provide this sort of automated weather station at a limited number of smaller, uncontrolled airports that are located in remote areas.

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* Forty-seven government-run controlled airports and one privately operated controlled airport.

† For fully ICAO compliant METARs the automatic systems may need to be augmented by manual additions during hours that the airport is open (see Appendix A).

3.2 Use networking to eliminate multiple manual data entries.

Current Colombian data entry procedures require multiple manual data entries as a routine part of making the required daily reports. METARs that have just been prepared on a workstation are written down on a piece of scratch paper and then retyped by hand into a different workstation. The requirement for multiple entries delays the transmission of weather observations, takes time away from other tasks, and makes it more likely that there will be typing errors in a data transmission. With fully networked workstations, automatically generated data reports can be disseminated without human intervention or can be reviewed by an observer and then transmitted without having to retype the entries. Even in instances where the meteorologist still needs to manually enter a report or TAF it would only have to be prepared a single time, reviewed for errors, and then sent on its way.

3.3 Issue TAFs for all controlled airports.

At present, TAFs are only issued for seven of Colombia's eight international airports. Flights to domestic airports, however, would also benefit from accurate terminal weather forecasts. Increasing the number of routine TAFs from 7 to 47 or 48 would be a major undertaking and would require a substantial increase in forecasting staff (see Working Paper Number 3).

3.4 Issue SIGMETs and AIREPs as required.

The failure of Colombia to issue SIGMETs and AIREPs is a major deficiency that can compromise aviation safety. Changing the status quo will require training, reviews of guidelines and procedures for issuing SIGMET and AIREP reports, and expanded observational and operational capabilities. SIGMETs, in particular, require a good situational awareness of areas of hazardous weather (see Section 3.6). Operationally, there is also a need for computer-assisted templates for preparing AIREPs and SIGMETs that will facilitate the rapid preparation of the reports, combined with networked workstations that can transmit the reports via the AFTN and Washington WAFS uplink without them having to be retyped (see Sections 3.2 and 4.12).

3.5 Improve the availability and use of upper-air observations from radiosondes.

While Colombia has, on paper, an impressive upper-air sounding system with five radiosonde sites, routine soundings are only available once a day at no more two or three sites. Perhaps more importantly, aviation forecasters do not seem to be using the standard thermodynamic analysis tools that are central to forecasting convective activity. One of the most important areas for improvements identified by the EarthSat review of the current Colombian aeronautical meteorology system is the need for improved routine use of upper air soundings. This will require a substantial training effort, coupled with hardware and software upgrades to the radiosonde systems and additional funding to permit the more frequent launch of radiosondes (see Section 4.5).

3.6 Expand and improve the use of remote sensing technologies for situational awareness.

Perhaps the most important aspect of situational awareness is developing an understanding of the locations and movements of weather systems within the Colombian airspace. While numerical weather prediction models, surface observations, and upper-air soundings can go a long way in helping a forecaster understand the overall meteorological situation, the routine use of remote sensing observations such as satellite imagery, weather radars, and lightning detection systems can give the forecaster a clearer view of rapidly evolving weather conditions (see Sections 4.6, 4.7, and 4.8). This kind of situational awareness is critical for issuing SIGMETs (see Section 3.4) and contributes to the efficient operation of the Colombian airspace.

The successful introduction of advanced remote sensing technologies will require the identification of a number of science specialists who would receive advanced training in these technologies and become system specialists responsible for monitoring system performance and training other staff in the use of these technologies.

3.7 Slowly transfer existing staff away from routine observational tasks to higher-level meteorological activities.

With the gradual introduction of fully automatic surface observing systems, it should be possible to transfer MET observers to higher-level responsibilities including system maintenance and calibration, forecasting, and pilot briefing. Such a transition will necessarily require an extensive program of education and training.

3.8 Develop a Colombian mesoscale numerical model for use in preparing TAFs.

High-resolution mesoscale models can provide considerable assistance to those assigned the responsibility of preparing forecasts. For use in Colombia it will be necessary to customize the model to emphasize local topographic and land surface effects that can dominate the daily local weather patterns. A modeling initiative would represent a major expansion in meteorological capabilities in Colombia and might best be approached through a cooperative effort with university researchers or regional forecast centers located outside of Colombia.

The successful introduction of locally run mesoscale numerical models will require the identification of a number of science specialists who would receive advanced training in numerical weather prediction and become specialists responsible for monitoring model performance and training other staff in the effective use of models in operational forecasting.

4 Infrastructure Options and Observational System Upgrades

Aviation safety requires accurate and dependable meteorological measurements. EarthSat recommends that Colombia concentrate on purchasing high-quality meteorological systems and then invest the proper funds to maintain them in accordance with manufacturer standards and ensure compliance with warranty conditions. This approach may mean a more gradual expansion of meteorological services than could be done by buying less expensive systems, but will be more efficient in the long run.

We feel that airport meteorological systems and supporting infrastructure should be provided by, maintained by, under the control of, and operated by AeroCivil staff (or contractors to AeroCivil). This approach will make it easier to fully integrate these systems and operations with other airport services and communication links.

To the extent possible, procurements for new meteorological systems should emphasize demonstrated system capabilities and reliability as reflected by sales to other national and international meteorological agencies and through certification by the United States FAA or other national meteorological or testing agencies. It is also important to plan ahead for system integration requirements. Since many systems need to share and exchange data, it may be beneficial to acquire compatible hardware through a single, higher-level integration contract, with the actual observing systems being selected by the system integrator (see Sections 4.11 and 4.15).

The following subsections will discuss individual instrument systems that should be considered as part of the proposed upgrade to the Colombian aeronautical meteorology system. Each discussion includes general cost estimates for planning purposes. These estimates are based on our experience as well as general discussions with many of the system providers. The prices are for the vendor's standard configuration products and may not have all the specifications or enhancements that might be included in a procurement specification. In some cases, the cost of a standard product might be doubled by asking for special features or custom capabilities not normally provided (see the discussion in Section 5.2). Whenever possible we have tried to obtain a price estimate appropriate for international sales. It needs to be emphasized, however, that the price estimates provided are do not include transportation costs or import duties. Additional training may be required and some customization of the system may be required. No adjustments have been made for inflation, changes in the exchange rate, or payments to a Colombian representative or agent. The actual system costs will normally be higher then these planning estimates.

4.1 Automated surface meteorological stations and equipment.

Surface observations from airports are the heart of the current Colombian aeronautical meteorology system. Only five of Colombia's 47 controlled airports operate around the clock, meaning that most meteorological observations are intermittent. The first flights of the day are often delayed until METARs become available, and the lack of a full diurnal data base limits the accuracy of terminal forecasts and restricts the usefulness of airport climatologies.

EarthSat recommends that UAEAC initiate a program to shift to automated, around-the-clock meteorological observations (with automatic METAR preparation and dissemination) at all 47 controlled airports in Colombia. The use of automatic weather stations for routine aeronautical meteorological observations is discussed in the upcoming release of ICAO's "Manual on Automatic Meteorological Observing Systems at Aerodromes" (ICAO Document 9837, 2004) and is consistent with the CAR/SAM recommendation that "routine observations should be made throughout the 24 hours of each day except as otherwise agreed between operators, air traffic services units and the meteorological services unit concerned" (CAR/SAM Basic ANP, ICAO, 1999). To reach this goal we envision a gradual transition over the full ten-year period of our recommended plan.

The first real push towards the wide-spread use of fully automatic meteorological observing systems was the ASOS (Automatic Surface Observing System) program in the United States. This effort began in the early 1990's as a joint program of the FAA, the National Weather Service (NWS), and the Department of Defense. ASOS systems are comprised of a large number of different weather sensors from many different vendors unified by custom integration and sophisticated processing software. While ASOS systems cannot evaluate all possible METAR options, the systems have proved to provide a valuable, uniform, and reliable observational data base for weather observations and airport operations. Over 600 ASOS systems have been installed in territories of the United States.

In addition to ASOS, the NWS and FAA have a number of other automatic weather reporting systems created for specific roles within the U.S. national meteorological observing system, including AWOS (Automatic Weather Observing Systems), SAWS (Stand Alone Weather Systems), and AWSS (Automatic Weather Sensor System) to name a few. AWOS systems can be provided in a number of different configurations and the AWOS specification terminology has come into widespread use (see Table), but is not necessarily standardized between vendors.

For automatic weather systems, the individual sensors are just the starting point. The real distinguishing feature of these systems is the ASOS-style processing algorithms that combine time-averaged observations from different sensors to infer what is happening meteorologically. In a mature system, the meteorological observations are continually monitored for data quality and reliability.

AWOS-A	Contains only dual-pressure sensors for reporting altimeter settings.
AWOS-1	Contains sensors for pressure, wind, temperature, and dew point.
AWOS-2	Contains all AWOS-1 sensors, plus a visibility sensor
AWOS-3	Contains all AWOS-2 sensors, plus a cloud height sensor
AWOS-3P	Contains all AWOS-3 sensors, plus a precipitation identification sensor.
AWOS-3T	Contains all AWOS-3 sensors, plus a thunderstorm/lightning reporting.
AWOS-3P/T	Contains all AWOS-3P and AWOS-3T sensors.
AWOS-4	All the AWOS-3 sensors, plus precipitation occurrence, type, and accumulation; freezing rain; thunderstorm; and runway surface condition sensors.

Colombian airports currently have many different meteorological systems that are in varying degrees of use. In conjunction with the transition to automated weather stations at all controlled airports, EarthSat also recommends that out-of-date and unused instrumentation be removed. In particular, many airports now have WMO-style synoptic weather stations, usually termed "Met Gardens." These MET Gardens do not, in general, meet current ICAO standards for airport observations. They should be phased out, at least as far as aviation support is concerned. Many of these stations, however, have a long history of manual observations and are likely important to IDEAM for synoptic, hydrological, and climatological applications (see Appendix A, Table A-1), but they do not merit continued support by UAEAC. If these stations are important to IDEAM, AeroCivil should permit these observations to be continued at their present locations by IDEAM staff and volunteer observers.

All controlled airports in Colombia are equipped with windsocks, aviation barometers for altimeter settings, and an anemometer installed on top of the control tower. In many of the smaller airports, these are the only weather instruments available. While these instruments, particularly the control tower anemometers, do not Meet ICAO standards, they provide a valuable backup should other observing systems fail and should be preserved, maintained, and periodically upgraded or replaced. This basic back-up system should also include a thermometer for monitoring the outside air temperature.

Official airport observing stations should be installed along or adjacent to the runways with the wind observations taken at a standard height. These observations, and not observations made with control tower or MET Garden systems, should be used for generating METARs. The minimum ICAO requirements for Colombian METARs are specified in the CAR/SAM Basic ANP (ICAO, 1999). In particular, the routine hourly observations are expected to always include temperature, dew point, and pressure (in the form of QNH). In addition to these basic parameters, Annex 3 (ICAO, 2001) specifies wind speed and direction as mandatory. This configuration is often referred to as AWOS-1 (see EarthSat Working Paper Number 1, Section 5.1.4) and represents the minimum acceptable airport observation set capability. The Sutron automated weather stations installed at a number of UAWAC airports are designed to emulate the capabilities of an AWOS-1 station. Annex 3 also mandates that METARs include reports of visibility and cloud cover (cloud type, amount, and base height), although these measurements are often made manually. EarthSat, however, strongly recommends that automatic observations of cloud ceiling and visibility be included in the basic observing station configuration, upgrading the recommended observing station standard to AWOS-3. Ceiling and visibility problems are wide-spread throughout Colombia and need to be monitored routinely, 24 hours a day. These observations will provide assistance to weather forecasters, assist in planning for aircraft operations, and are essential for pre-flight weather briefings.

Power requirements: While the basic meteorological sensors in an AWOS-3 station can be powered by solar panels and backup batteries, ceilometers require AC line power. This can be a problem for Colombian airports that do not routinely run power lines to all areas of the airport. For routine use at airports without ILS runways, it may be acceptable to separate the ceilometer from the rest of the sensor suite and installing it at a location nearer to the terminal building or other area with easy access to line power. Meteorological systems that are powered with line power need to be provided with the same provisions for backup power as given other essential airport systems.

Additional sensor options beyond the basic AWOS-3 configuration can add automatic analysis of the present weather (essentially an automatic precipitation identifier) and an indicator of thunderstorm activity in the airport vicinity. EarthSat does not recommend adding these options at this time. All automatic systems should include the option of manual entry of additional information to the basic automatic reports. This feature allows an observer with meteorological training to add comments specifying the current weather (rain, drizzle, hail, etc.) and a more detailed description of the cloud cover and structure beyond the basic cloud base height measurement from the ceilometer. These manual observations, of course, would only be available during hours that the airport is open.

Most AWOS systems come with voice synthesis software than can be used to generate weather summaries that can be broadcast over an airport's Automatic Terminal Information Service (ATIS) system – a VHF radio that continually plays a taped loop with airport weather and other information. Under the CAR/SAM Basic ANP (Table AOP-1), designated international airports are required to have operational ATIS systems. In most airports the ATIS system is considered a navigation aid and is sometimes installed at a VOR. If no ATIS system is available, the AWOS can be augmented by its own radio to generate ATIS broadcasts.

All controlled airports in Colombia should be equipped with ATIS systems set up to broadcast the current weather and other airport information.

The privately operated and controlled airport at La Mina (El Cerrejón) has recently been equipped with an AWOS-3P/T automatic weather station, with an identical automatic weather station installed at the nearby Puerto Bolivar airport. If possible, EarthSat recommends that METARs from La Mina and Puerto Bolivar be incorporated into the OPMET data bank as part of the Colombian aeronautical meteorological system.

Accuracy standards for the individual sensors that are integrated into the AWOS systems are specified by ICAO in Annex 3, Attachment B (ICAO, 2001), in WMO Technical Regulations (WMO, 1993; WMO, 2001), and in FAA Advisory Circular Number 150/5220-16C. High-quality modern sensors that comply with the designated standards are widely available. The more critical issues are reliability and system integration. While it is difficult to evaluate the internal software of the AWOS system, the critical differences between systems are often contained in the internal diagnostics, quality control, archival and playback capabilities, and options for remotely monitoring system behavior. Perhaps the best indicator of a system's overall quality is being selected for operational use by recognized national authorities, such as the U.S. FAA, or by being awarded FAA certification (see Section 5.2).

A high-quality AWOS-3 system can be purchased for about US$ 65,000 – US$ 75,000 when purchased in multiple units. Civil and electrical works for this level of system might cost US$ 20,000 with system installation adding another US$ 10,000 — for a total of just over US$ 100,000.

Although not available commercially, the cost to duplicate a single full-featured ASOS system is usually estimated to be over US$300,000. For comparison, high-quality AWOS-1 systems with limited processing capabilities are available for about US$ 30,000 (exclusive of installation and civil works). Both visibility sensors and ceilometers are expensive and drive up the cost for AWOS-3. High-quality visibility sensors are normally priced in the US$ 10-15,000 range, while ceilometers will usually cost in excess of US$ 20-25,000.

RVR systems are essentially specialized visibility systems optimized for aviation use in low visibility conditions (see Section 4.2). Although not always a standard feature, automatic observing systems should be able to ingest RVR measurements so that they can be included in routine, automatic METARs and for data archival and aerodrome climatologies. In an integrated weather system that includes its own RVR measurement, some vendors make dual-use of the visibility sensor for stand alone observations as well as for input into the calculation of the runway visual range.

EarthSat estimates that the overall cost of the comprehensive upgrade of the surface observing systems at all Colombian controlled airports (including civil and electrical works) will be a bit over US$ 4,500,000.

The gradual introduction of these new observing systems will allow careful monitoring of system performance and an evaluation of the suitability of the existing Sutron systems over a prolonged evaluation period.

Proper installation and maintenance is essential for an airport automated weather station to continue to function reliably and accurately. Most vendors recommend that each site be visited four times a year for preventative maintenance, cleaning, and an overall system check. Calibration checks are normally only done once a year, unless there has been a problem reported. Properly maintained, a good quality AWOS should have a lifetime in excess of 15 years.

In addition to the weather stations installed at for operational use at airports, a limited number of additional weather stations should be obtained for use in training. These systems could also be used as emergency backups that could be temporarily installed while a defective system is awaiting repair (see Section 5.3).

Approx. Acquisition Cost (for planning purposes): US$ 4.5 million, spread over 10 years.

Potential Vendors: All Weather Inc. and Vaisala Inc. provide AWOS systems to the FAA and are certified AWOS vendors (see Section 5.2). Coastal Environmental Systems provides comparable certified systems to the U.S. Air Force and the FAA. Recently two additional companies, Belfort and Potomac Aviation Technology have received FAA certifications for their AWOS systems. Belfort makes an AWOS-2 system and Potomac makes an AWOS-1 system. In both cases, however, these systems are intended for smaller, non-federal airports and are designed as independent, stand-alone sensors with radio or telephone access, and not part of a networked system connected to the AFTN.

Vaisala also manufactures an AWOS equivalent airport weather systems that are designed to operate in an integrated environment as part of a sophisticated airport weather information system (MIDAS-IV) that may be attractive for airports with windshear enhancements or ILS systems.

4.2 RVR, ceiling, and visibility.

ICAO standards and recommended practices require the installation of integrated automated systems for remotely monitoring the surface wind, runway visual range, and cloud height on runways intended for Category II and III instrument approach and landing operations. These same systems are recommended for all runways intended for Category I instrument approach and landing operations.

Colombian airports with Category I or II Instrument Landing Systems (ILS) currently include Bogotá (El Dorado), Rionegro, Barranquilla, Leticia, Cali, Cúcuta, and San Jose del Guaviare. Additional ILS systems are planned for airports at Cartagena, San Andres, Pasto, and Bucaramanga.

RVR measurements are essentially high-quality runway visibility observations designed for use in times of restricted visibility. By ICAO standards, they should be accompanied by automatic ceilometer systems for measuring cloud base heights.

RVR systems are highly specialized. Currently there are two different technologies for measuring RVR. The traditional system is based on a long baseline transmissometer, while a number of newer systems have been introduced that make use of shorter baseline forward scattering measurements. Most recent examinations of RVR technologies have shown that high-quality, well-maintained and well-calibrated forward scattering instruments are quite reliable. The current FAA-purchased RVR systems used in the United States are forward-scatter instruments manufactured by Teledyne Controls.

While transmissometer-based systems are still considered the reference standard, forward-scatter instruments are easier to install, calibrate, and maintain. Transmissometers may be superior for tracking visibility reductions due to smoke, but are very sensitive to alignment and subject to dirty windows.

RVR systems are typically installed in pairs, with one set of sensors monitoring the visual range at each end of the runway and may be further enhanced with an additional RVR at center field. If instrumented landings are only conducted in one direction, a single sensor installation could be acceptable. Traditional transmissometer-based RVR systems with processing systems and displays for both ends of a runway would cost about US$ 120,000 while a similar system only installed at one threshold might coat about US$ 75,000. These figures do not include installation or civil and electrical works, perhaps totaling about US$ 25-30,000 per site. A pair of forward-scatter RVR sensors and associated software and displays would cost about US$ 75,000 or, for coverage at only one end of the runway, perhaps US$ 50-60,000 depending on the vendor. The forward-scatter instruments should also be less expensive to install (perhaps US$ 20-25,000 including civil and electrical works).

In late 2004, AeroCivil contracted with Vaisala to install three transmissometer-based RVR systems at Rionegro, along with an accompanying ceilometer. At the same time, the existing RVR systems at Barranquilla and Cali were scheduled for repair so that they can be returned to service. To bring Cali up to full ICAO compliance, AeroCivil also contracted for a new ceilimeter to be installed at Cali. In 2005 AeroCivil plans to upgrade the RVR and ceilometer systems at Bogotá's El Dorado airport to full ICAO compliance by purchasing two replacement RVR systems and an additional ceilometer.

The remaining ILS runways at Cúcuta, Leticia, and San Jose del Guaviare should also be equipped with RVR and ceilometer systems. For these CAT-I runways, EarthSat recommends that UAEAC provide a single RVR and ceilometer system for these airports, integrated with an upgraded automatic weather station. With the expectation of providing ILS capabilities at Cartagena, San Andres, Pasto, and Bucaramanga EarthSat recommends that these airports also receive RVR systems as part of the automatic weather stations upgrades recommended for all Colombian controlled airports. While we expect that AeroCivil will install transmssometer-based RVR systems at Bogotá's El Dorado airport, we recommend that the remaining airports that need RVR systems be provided with forward-scatter based systems, reflecting current trends towards the use of forward-scatter systems with their relative ease of installation, calibration, and maintenance.

These upgrades will require acquisition of two new transmissometer-based RVR systems, plus seven forward-scatter RVR systems for an overall cost in the vicinity of US$ 480,000 plus about US$ 180,000 for civil and electrical works and installation for all seven sites.

A companion ceilometer for the new RVR systems in Bogotá should cost about US$ 30-40,000 if it can make use of existing displays. The other ILS airports should be able to make use of the ceilometers that are an integral part of the EarthSat recommended AWOS-3 automatic weather station configuration, if these basic systems are fully integrated with the new RVR systems. Integrated systems of this sort will provide improved airport weather reports and save money.

Approximate Acquisition Cost (for planning purposes): US$ 700-800,000 total, not counting the ceilometer systems already specified as part of the recommended AWOS-3 systems to be provided at every controlled airport.

Potential Vendors: Vaisala Inc. and All Weather Inc. each produce their own ceilometers for their FAA installed AWOS systems. Both companies also make RVR systems, as does Coastal Environmental Systems. The FAA's current RVR systems are supplied by Teledyne Controls, but this system is highly customized for US airports and is very expensive. At present the FAA does not have a formal RVR certification program for non-federal airports.

4.3 National network for altimetric adjustment.

Careful adjustment of aircraft altimeters is a critical safety concern for aviation. This is particularly true in Colombia where frequent periods of low ceilings and restricted visibility are a dangerous combination with rough terrain and high mountains. One possible way to assist pilots in making proper adjustments to their aircraft altimeters during flight is to provide a national network of barometers that would broadcast the correct altimeter settings for that immediate area over limited range radios.

Fully automated weather systems of this sort (usually designated as AWOS-A) are a standard commercial product and are available from a variety of vendors for approximately US$ 12,000 per site plus installation and civil and electrical works and can be equipped with their own ATIS-style VHF radios. These additional costs might be expected to average about US$ 5000-8000 per installation. These systems would normally be installed at small airports without a more comprehensive weather system, or could be placed at critical locations such as mountain passes.

While this sort of system could be a valuable part of a national aviation support system, it may not be needed in Colombia. We have already recommended that all 48 Colombian controlled airports be equipped with exactly these capabilities including short range radio transmitters, augmented by additional meteorological information. With fully automatic systems, these observations would be available around the clock even while many airports are closed overnight. While there are a number of areas where additional reporting stations may be useful, these data voids may be better served by installing a few additional full-featured automated weather stations. Placing automatic barometers on mountain passes or other dangerous terrain would only be valuable if the observations were totally reliable. Otherwise, the installed system could cause accidents instead of preventing them.

Recommendation: Every effort should be made to install full-featured automated weather stations at all controlled airports instead of introducing a parallel network of weather stations with only altimeter capabilities. Individual altimetric reference stations may be appropriate at some sites such as uncontrolled airports in remote areas, but even in these cases it would be desirable to add additional weather information such as wind, temperature and dew point — essentially an AWOS-1 configuration.

Although several different vendors can deliver AWOS-A systems, it is critical to specify that the systems use dual-barometer configurations that are FAA certified. Every system should make use of existing airport ATIS radio systems or, if an ATIS is not available, augment the AWOS-A by a stand-alone ATIS.

4.4 Data exchange with en-route aircraft

4.4.1 Downlinking digital weather data from en-route aircraft.

Modern commercial aircraft are surprisingly good data collection platforms for meteorological information. Their normal instrumentation includes capabilities for monitoring the outside air temperature, as well as the aircraft's pressure altitude and air speed. Combined with their sophisticated navigation capabilities this information can be used to extract the ambient wind speed and direction. With modification to the on-board software it is also possible to produce an objective measure of the level of turbulence that the aircraft is encountering. In some cases, additional sensors are being added to aircraft to provide a high-quality measurement of the moisture content (humidity) of the outside air.

Using existing digital communication links, such as ASDAR (Aircraft to Satellite Data Relay) and ACARS (Aircraft Communication Addressing and Reporting System), this information can be automatically transmitted to ground receiving stations where the meteorological information can be made available to national and international observational data bases (Moninger, 2003).

The WMO and ICAO expect that these data reporting systems, collectively named AMDAR (Aircraft Meteorological Data Reporting), are going to become increasingly important data sources for aviation meteorologists, allowing routine monitoring of flight level winds and turbulence, as well as vertical temperature soundings during landings and take offs. The fundamental problem with AMDAR is that since it is based on existing commercial data links, all the weather transmissions are charged a fee which has to be paid by the airline operator or by a responsible government agency.

Several national AMDAR programs have already been established and Colombia should evaluate the AMDAR capabilities over its airspace, participate in WMO regional AMDAR meetings, and begin planning for future participation in this global program (WMO, 2004).

In a related program termed Tropospheric Airborne Meteorological Data Reporting (TAMDAR), special weather sensors have been installed on regional airlines to automatically transmit high-quality weather information, including icing and turbulence, to ground stations (Daniels, 2004).

While current upgrades to Colombian meteorological data processing and data integration systems should be designed to allow the future incorporation of AMDAR data sets, EarthSat does not recommend any concrete actions to initiate a special Colombian AMDAR program at this time. Other priorities are more pressing.

4.4.2 Uplinking digital weather data and products to en-route aircraft.

In the same way the data can be automatically downlinked from en-route aircraft, weather information can also be uplinked to suitably equipped aircraft.

The most basic weather data uplink capability is the short range ATIS radio broadcasts from ground stations and airports. Digital ATIS data links are also employed in some areas, but are not as common since they require special receivers and displays to be installed on the receiving aircraft.

In the United States, the FAA has recently issued an announcement (Advisory Circular Number 00-63, 2004) of a national system for cockpit displays of digital weather and operational information. This system (Flight Information Services Data Link, or FISDL) is based on a government-sponsored national radio network that can be used to uplink information to aircraft that are equipped with suitable receiving systems and displays. The onboard displays and associated software are being provided by commercial companies and must be purchased by the aircraft owners. For the most part, these systems are intended for small planes used for general aviation.

The initial products in this system are expected to be text messages of standard weather products such as SIGMETs, AIREPs, and TAFs. Commercial vendors are expected to develop additional value added products of their own, on a "pay for service" basis.

In a separate experimental program termed TWIP (Terminal Weather Information for Pilots), the FAA experimented with sending line printer depictions of terminal area radar imagery to commercial aircraft equipped ACARS data systems and printers. Line printer graphic images, however, are of limited value and would need to be replaced with higher resolution color displays before achieving wide-spread acceptance.

Perhaps the most important application for this sort of technology would be to provide weather updates to en-route aircraft on long distance international routes. There are a number of test programs addressing this application, including programs that provide weather information customized for individual aircraft and updated automatically during flight, but none of these systems are ready for service. The fundamental limitation to these programs are the requirement for high-speed data links to support sophisticated graphical weather products and the difficulties in modifying certified cockpit avionics for new displays and applications. Like with AMDAR, the en-route communication links are operated by commercial companies such as ARINC or SITA and charge the user for every data transmission.

At present, EarthSat does not recommend that Colombia try to implement its own system of automatic weather data uplinks to en-route aircraft. Other priorities are more pressing.

4.5 Radiosondes and upper-air sounding systems.

Colombia's upper-air sounding systems were discussed in considerable detail in Working Paper Number 1. While we received conflicting information on the condition of the sounding systems, it is clear that significant upgrades are needed, as well as increased operational funding, to be able to launch a full program of radiosondes.

Colombia has five upper-air sounding sites and all are important. At present only three of these stations appear to be launching radiosondes and even these stations do not necessarily launch a sounding every day. The initial goal of the upgrade should be to get all five of these systems back into operation with a single sounding (at 12Z) from each station. The longer term goal should be to maintain the one-a-day launch schedule from 4 stations while adding a second balloon launch every day in Bogotá – fulfilling Colombia's WMO commitment.

Although four of the five current sounding stations are located at controlled airports,[‡] Colombia's upper-air sounding program is managed and operated by IDEAM. Although we generally feel that observing systems that are located at airports should be owned and managed by UAEAC, the radiosonde stations could well be an exception. While soundings are essential for supporting aviation, the international upper-air sounding program is organized under the auspices of the WMO, and IDEAM is Colombia's designated WMO representative.

IDEAM, however, is apparently going to need some assistance with their radiosonde program. At present, IDEAM either doesn't receive an adequate radiosonde budget, or doesn't make radiosondes a priority. If necessary, the budget problem could be solved by having other agencies that need upper air soundings, like UAEAC and FAC, transfer some of their own funding to IDEAM in support of the Colombian national radiosonde program. With the cut back in IDEAM staff providing meteorological services at Colombian airports that is being proposed in this Working Paper and in Working Paper Number 3, however, IDEAM may not be able to support the staff needed to launch the radiosondes at all five sounding stations. In this case, IDEAM may need to delegate the <u>operational support</u> of their radiosonde program to UAEAC or FAC, while maintaining its current upper level management role with respect to the WMO. Under this scenario, FAC might provide staff and funding for radiosondes launches from FAC bases such as Marandúa AB or from joint use airports such as Leticia, while UAEAC could provide staff and funding for radiosondes at other controlled airports. All of the soundings, of course, would be shared with the other agencies and transmitted internationally by means of IDEAM's WAFS uplink to Washington.

At present, the San Andrés upper-air site (InterMet radio theodolite and Sippican sondes) is partially supported by the U.S. National Weather Service through the provision of radiosondes from the U.S. inventory. This is a major contribution and it is important that

[‡] We understand that there are plans to move the only non-airport sounding site (Las Gaviotas) to the controlled airport at Puerto Carreño. Marandúa Air Base might also be a suitable location.

Colombia make full use of these donated resources with a reliable schedule of balloon launches, careful quality control of the upper-air soundings, timely international dissemination of the soundings, and thoughtful use of the soundings in support of Colombian weather forecasts for aviation and for the public at large.

All four of the other radiosonde stations are equipped with Vaisala sounding systems – three Vaisala MW15 sounding systems with DigiCORA II processing systems and an older MW11 system that uses a DigiCORA I processing system. At present, all of the Vaisala systems are using RS80-15G (GPS wind-finding) sondes.

The sounding station in Bogotá has been having problems with radio interference, which can be resolved by a shift to a newer model radiosonde, the all-digital RS92. The older analog RS80 sondes are going to be discontinued in the near future so there is good reason for Colombia to make a full transition to the RS92 sonde for all of the Vaisala systems.

The MW15 can be upgraded to be compatibility with the RS92 radiosondes at an approximate cost of US$ 15,000. An alternative approach would be to upgrade to Vaisala's newest radiosonde system, the MW21 with DigiCORA III processing software running on standard personal computer platform that can be networked with other computers in the weather station environment. Having the radiosonde processing system be fully networked with the rest of the airport environment would greatly improve the rapid transmission of radiosondes to UAEAC, IDEAM, and FAC forecasters and get them into the international data banks with greater reliability. The new systems also make use of significantly improved software, including a METGRAPH option for plotting soundings in skew-T log-P and Tephigram formats. The MW21 is almost a completely new system with an upgrade from the MW15 to the MW21 priced at approximately US$ 120,000 (plus about US$ 9,000 for the full featured METGRAPH option).

Upgraded MW15 systems will be able to use either the analog RS80 or the digital RS92 radiosonde, meaning that Colombia can easily use up the remaining sondes in their inventory even while transitioning to the newer model radiosonde.

EarthSat recommends that Colombia purchase one new Vaisala MW21 system with DigiCORA III including a full version of METGRAPH for installation in Bogotá, and then transfer the existing Bogotá MW15 to replace the MW11 that could then be retired.

We additionally recommend that Colombia upgrade all three of its Vaisala MW15 systems to be able to use the new RS92 radiosonde. These changes should solve the current radio interference problems being experienced in Bogotá while at the same time moving away from an older model radiosonde that is being discontinued.

We recommend that this transition be done as a 2-year effort. The initial year would focus on upgrading the existing MW15 at Bogotá and acquiring a replacement MW21 at the same time. After the new MW21 is installed, the upgraded MW15 can be transferred to replace the MW11 unit. The two remaining MW15 systems would then be upgraded in the second year, giving Colombia a fully functioning radiosonde network.

Eventually Colombia should upgrade all the Vaisala radiosonde systems to the MW21 with DigiCORA III. These systems have processing software and can be directly connected to a network communication interface. The older systems, on the other hand, do not have a network interface and the operator has to copy a processed sounding to a disk and carry it to another, networked, computer to be able to send it to IDEAM for subsequent transmission to Washington via the WAFS uplink. In the short term, however, we feel that acquiring a single new MW21 while upgrading the MW15 systems is a cost-effective way to get Colombia's upper-air systems back in operation. To ensure the rapid dissemination of the upper-air soundings we recommend that new, networked computers be installed alongside the MW15 DigiCORA II radiosonde systems so that the transfer of the processed sounding can be accomplished quickly and easily.

Radiosonde System Upgrades:

The Year 1 acquisition of a new MW21 (with METGRAPH) and a single MW15 upgrade (including a separate, stand-alone personal computer) will cost about US$ 150,000. The subsequent upgrade of two additional MW15 systems (plus two networked personal computers) in Year 2 will cost approximately US$ 40,000.

Continuing Annual Radiosonde Costs:

The most significant long term problem with Colombia's upper air program is the cost of the radiosondes. Single RS80 radiosondes (purchased in bulk) cost Colombia approximately US$ 140. The newer RS92 radiosondes are likely to be more expensive, perhaps US$ 180 per radiosonde. For a single site, this means that a single daily launch will require almost US$ 70,000 per year, or almost US$ 400,000 per year for the full WMO program of six daily soundings (two daily Bogotá soundings, and a single sounding per day from the other four sites).

It is often difficult to find adequate financial support for this sort of continuing operational expense. Distributing the radiosonde support among UAEAC, IDEAM, and FAC may make it somewhat easier to fund this critical program.

Additional Training and Support:

In addition to upgrading the radiosonde systems and finding money to launch a full program of upper-air soundings, there is a clear need for a substantial training program in using soundings for forecasting convection and predicting the onset and clearing of areas of low level cloud and fog. There is also a critical need for forecasters to have graphical routines for plotting radiosondes on standard thermodynamic diagrams and analyzing sounding plots. A general discussion of the Colombian training needs is included in EarthSat's Working Paper Number 3.

4.6 Meteorological satellite data acquisition and processing system.

Colombia, situated directly beneath the GOES-12 geostationary meteorological satellite, is in a unique position to receive the highest quality satellite imagery of any country in North or South America. This satellite provides uniform coverage over all regions of the country at least once every 30 minutes. Monitoring the satellite imagery is an easy way to gain a good situational awareness of the evolving weather systems over the entire country and surrounding airspace.

Colombia should put a high priority on making full use of GOES imagery.

The full resolution, highest-quality digital data stream from the GOES satellite is termed GVAR data. This data set is transmitted directly from the GOES-12 satellite to a local ground-based system with its own 3.7-meter diameter antenna (see Figure 4.1) for reception, processing, and distribution. The GVAR data stream includes simultaneous imagery in five wavelength bands, ranging from 1 km resolution visible imagery to 4 km resolution infrared and water-vapor imagery. Receiving the GOES/GVAR data stream requires an L-band antenna coupled to a receiver and workstation. Stationary L-band antenna systems such as this are quite weatherproof and do not need a radome for protection.

In addition to the full GVAR data stream, lower resolution subsets of GOES data are available through WEFAX or LRIT transmissions. The older, analog, WEFAX broadcast is being discontinued in favor of the new, digital, LRIT transmission. Except as a backup system, WEFAX or LRIT receiver systems are not needed if there is access to the full GVAR data stream. If necessary, publicly available imagery from the Internet can be used as an emergency backup.

Figure 4.1: A 3.7 meter diameter L-band antenna used for receiving GOES/GVAR satellite imagery (illustration provided by SeaSpace, Inc.)

Additional weather satellite imagery is available from polar-orbiting satellites, such as the HRPT imagery from the NOAA series of satellites, but these POES (Polar-Orbiting Environmental Satellites) satellites only over fly Colombia twice a day and require special receiving systems with tracking antennas. While the POES satellites have some unique capabilities for monitoring agriculture and measuring sea surface temperature, they are of little operational use for supporting aviation. POES receivers, however, may be well suited for some of IDEAM's responsibilities.

In broad terms, there are three general categories of GOES/GVAR systems:

- Basic systems. These systems process the GVAR data stream to generate image files such as gif or jpeg. Satellite images can only be exported in standard image formats. Good displays and animation loops are possible, but without any real capabilities for interactive processing by a forecaster. These systems have limited remapping capabilities and usually only generate images in the satellite frame of reference. In general, these image-based systems do not attempt to produce integrated displays combining the satellite imagery with other data sets such as model fields, lightning, or radar. The image files are unlikely to have capabilities for custom map overlays or ATC landmarks. There are no capabilities for custom multi-spectral processing to generate advanced products. The current UAEAC system from Systems West is an example of this sort of basic receiving system.

- Mid-level systems. These systems process the GVAR signals to an internal digital format for display and processing. Limited remap capabilities are possible, as well as custom overlays. Data can be exported in a digital (not just image) format for external data integration and display. There may be custom, and perhaps even interactive, image enhancement capabilities, but no provision for multi-spectral processing or advanced product generation. These systems typically run on PC-based systems, frequently making use of the Windows operating system. Global Science & Technology's DirectMet system is a good example of a mid-level processing system.

- High-end systems. These systems offer full access to the digital data contained in the GVAR data stream for both scripted and interactive custom processing. Routine tasks can be scripted for ease of use, including multi-spectral processing and advanced product generation. These systems offer sophisticated remapping capabilities, a variety of built-in and custom overlay options, and versatile data export options and capabilities including the export of both digital data sets and image format files for use in web-based dissemination systems. Many of these processing systems run on LINUX platforms. SeaSpace's Terascan system is a good example of this class of GVAR receiving and processing system.

Good satellite imagery and advanced processing capabilities are critical supporting elements of custom data integration systems for forecasters and a key element in web-based systems for pre-flight pilot briefings. These applications are best served by a high-end satellite data acquisition and processing system.

While there is an immediate need for Colombia to replace its Systems West GVAR receiving system, it would be better to coordinate the purchase of a high-end GOES/GVAR receiving system with the provider of the data integration workstation (see Section 4.11). With this in mind, EarthSat recommends that UAEAC acquire a stand-alone LRIT system as a temporary replacement for the Systems West GOES receiver. A quality LRIT system should be a significant improvement over UAEAC's current satellite receiving system and allow the resumption of jpeg format imagery over the UAEAC Intranet server.

EarthSat also recommends that UAEAC proceed to acquire a high-end, GOES/GVAR receiving system for operational support of its aviation weather monitoring and forecasting responsibilities as part of a subsequent procurement for a forecasters' data integration workstation – with the system integrator selecting the satellite receiving station vendor. While a high-end system can be used for quite elaborate processing, routine processing steps can be run automatically from a prepared script for speed and ease of use in an integrated operational environment. Thus there is great benefit to having the system integrator select the ultimate GOES/GVAR ingest system and incorporate it into their workstation environment, while at the same time preserving the stand-alone capabilities of the GVAR system.[§]

In order to make good use of a mid-level or high-end satellite receiving and processing system, either as a stand-alone system or integrated into a larger system, it is critical to have one or more MET staff and engineers (electrical and software) assigned to specialize in understanding the system and become experts in its use. While the assignment does not have to be a full time responsibility, the satellite specialist should ultimately take the lead in training forecasters in using satellite data as well as assisting in the development of Colombian-specific materials for briefing pilots. These scientific officers should frequently attend regional and other international conferences on satellite meteorology such as the annual GOES users meetings held in the United States, and receive occasional assignment as a visiting scientist at an international satellite center, or receive specialized university training.

Sophisticated, high-end systems could cost in the vicinity of US$ 80,000-110,000. Mid-level systems have a wide range of prices, depending on their design and capabilities, ranging from as low as $30,000 to US$ 60,000 and up. In both cases these general price estimates should include basic system installation services without any significant requirement for civil works.

Satellite data processing systems need to be updated and maintained through a software support and system upgrade contract with the vendor. Software support contracts are often in the vicinity of US$ 5,000 per year. Hardware support contracts (or extended warranties) that provide for rapid replacement and repair of defective components are also available, and will typically be priced at an annual cost of about 15% of the original system purchase price.

LRIT systems are just now coming onto the market. Although intended as low-cost systems for users with limited budgets, these systems are full digital processing systems and are likely to be priced at around US$ 30,000.

[§] During the review of this report we learned that UAEAC has purchased a combined LRIT and GVAR satellite receiving system from IPS Meteostar.

Standard GOES/GVAR systems are well-tested, reliable, and coming down in price. Most systems should be able to be delivered and installed in a matter of months from a contract award. As a new product category, delivery times for LRIT systems are more uncertain.

Approximate Acquisition Cost (for planning purposes): US$ 30-40,000 for a LRIT system and US$ 80-110,000 for a high-end GOES/GVAR system as part of a separate, forecasters workstation procurement..

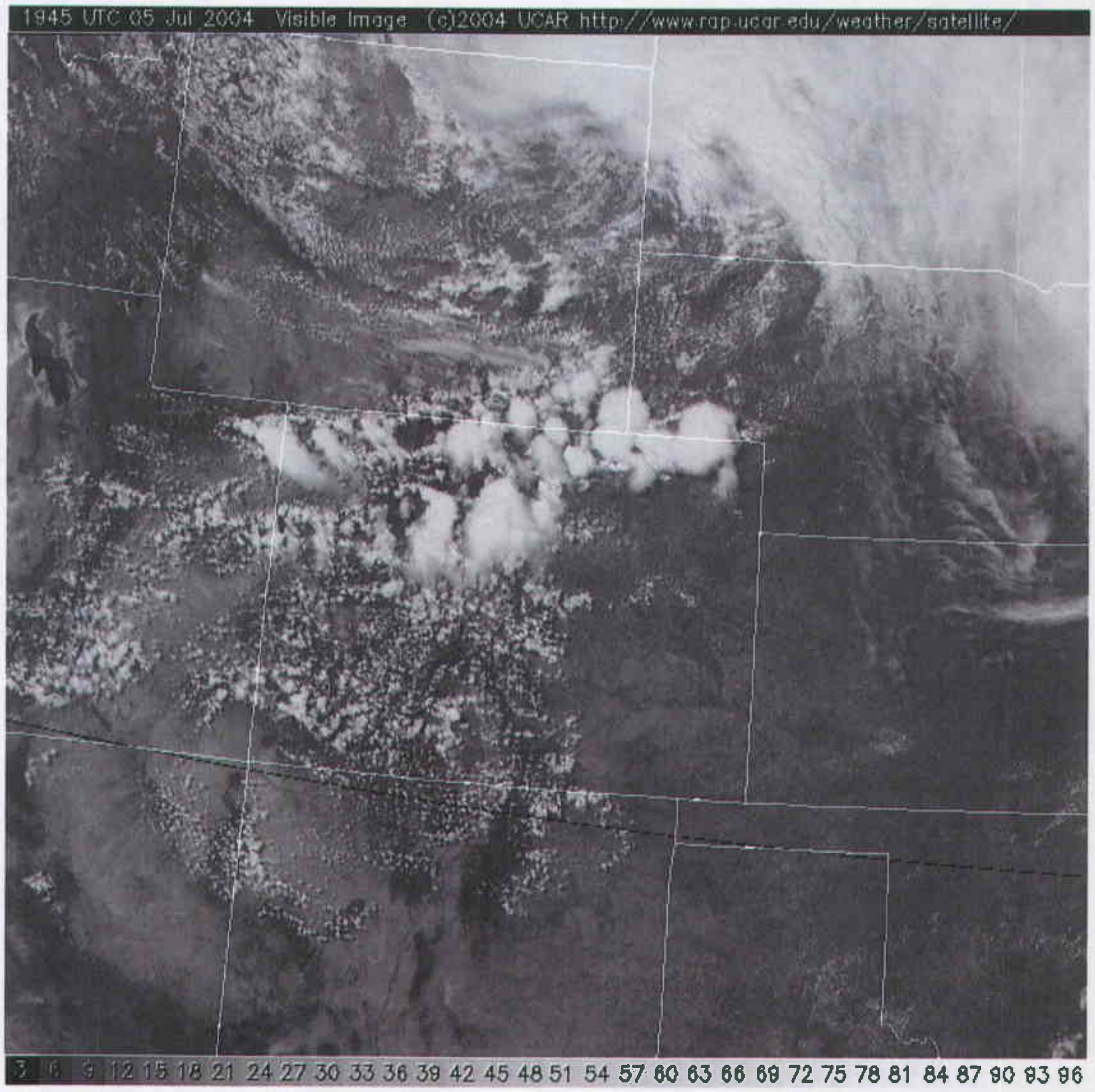


Figure 4.2: A high-resolution visible image over the western United States, remapped to a Lambert Conformal projection. Ground features and rivers are clearly visible, as well as small convective clouds.

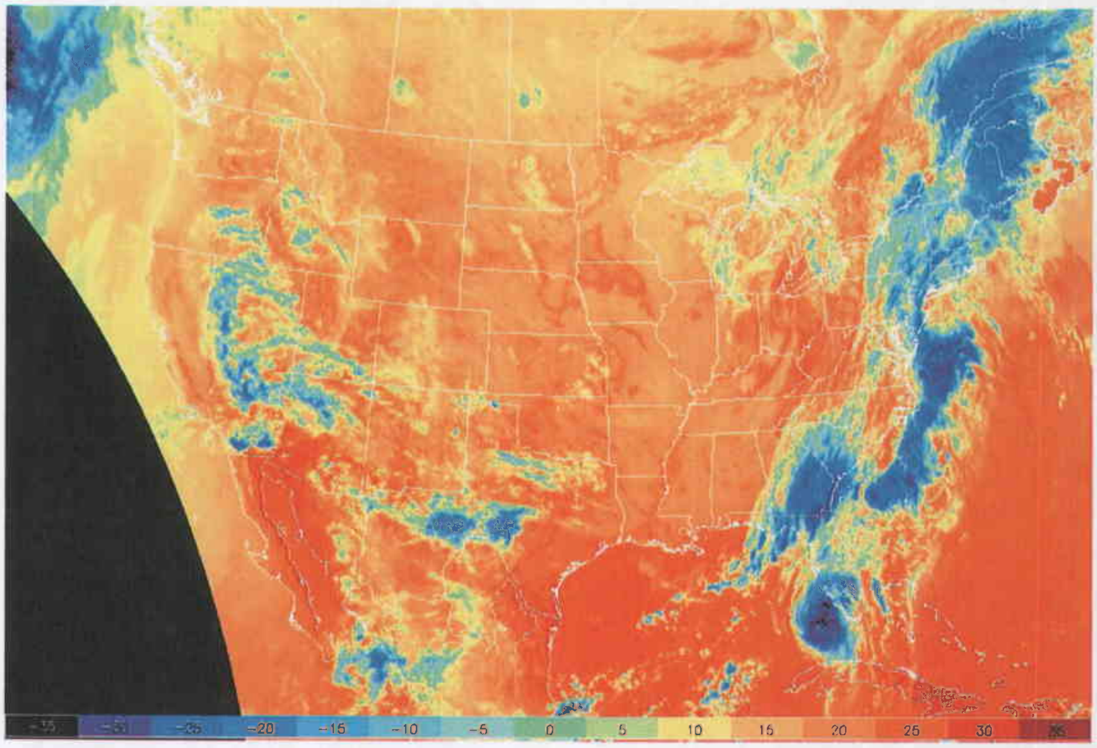


Figure 4.3: A Lambert Conformal remapped image over the continental United States (CONUS) illustrating imagery from a near-IR band.

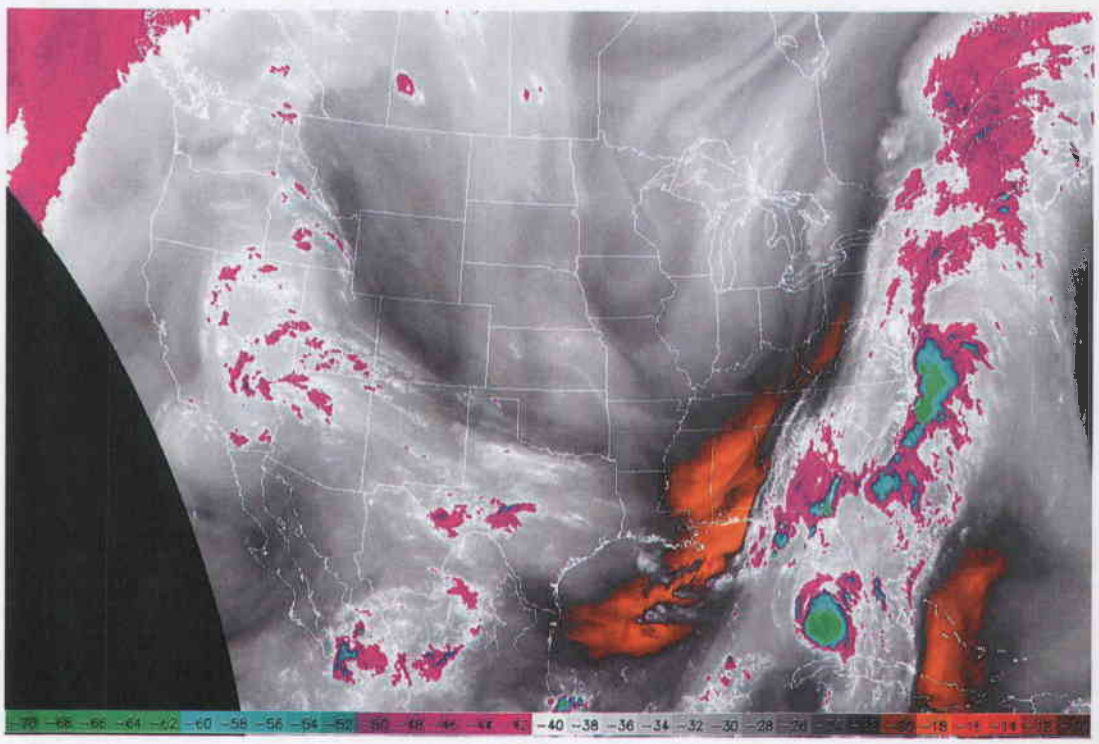


Figure 4.4: A Lambert Conformal remapped image over the continental United States (CONUS) illustrating imagery from the GOES water-vapor absorption band.

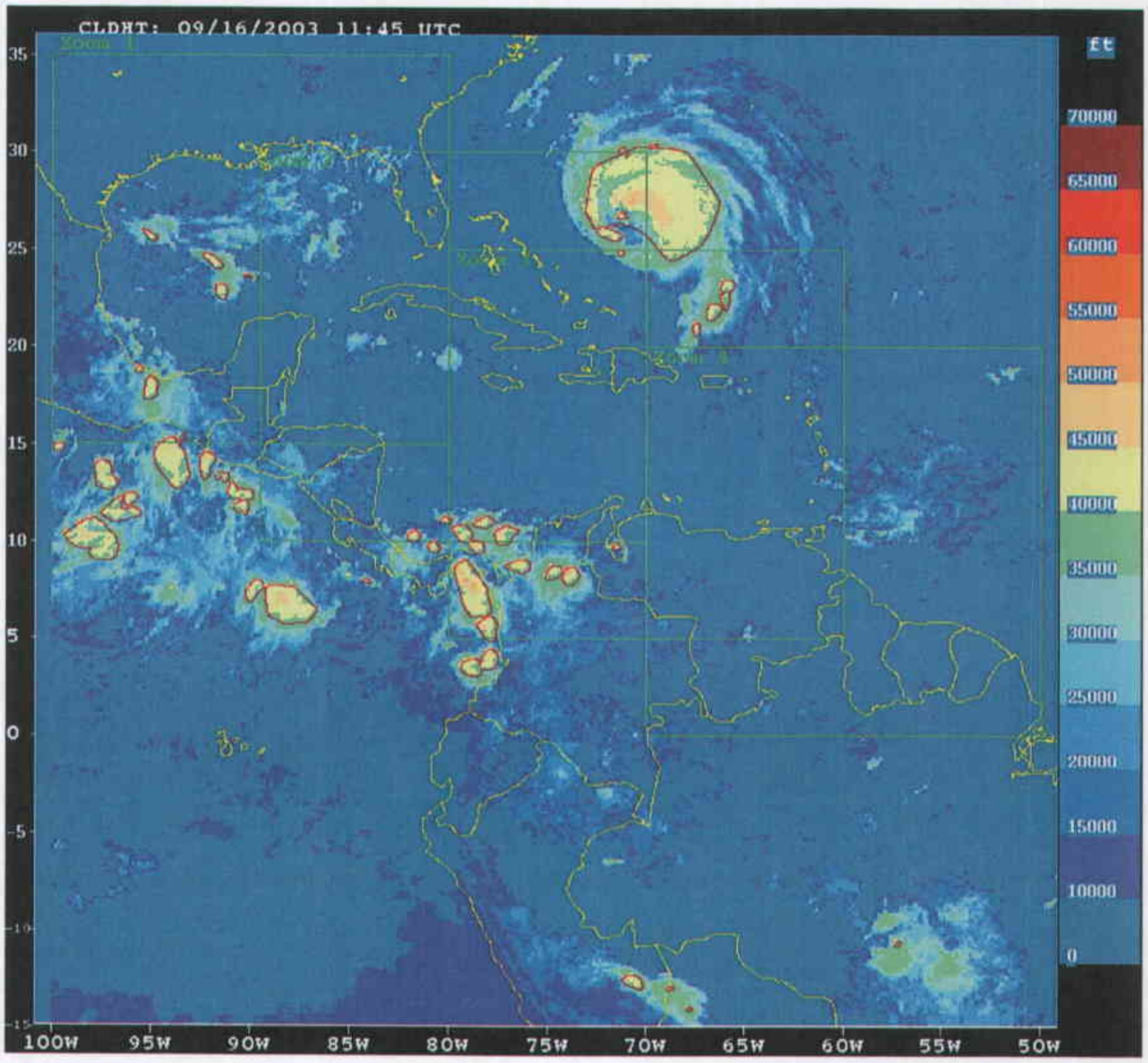


Figure 4.5: A custom GOES-derived aviation product showing cloud-top height over Colombia and the southern Caribbean. The cloud-top height is calibrated as standard en-route aircraft flight levels (Oceanic Weather Product Development Team, FAA/NCAR).

4.7 Meteorological radars.

Weather radars can play an extremely valuable role for monitoring hazardous weather systems for aviation. Severe convective storms, such as hurricanes and thunderstorms, are particularly well suited for tracking by weather radars. When a number of weather radars are integrated into a regional or national network they can provide forecasters and air traffic control personnel with a great situational awareness of the changing weather patterns that affect air traffic. Individual weather radars can also be very valuable for monitoring weather in the terminal area.

The weather channels that are often built into standard air traffic control radars are of limited value and can be misleading because there are fundamental differences in the radar designs necessary to optimize a system for weather detection or for tracking aircraft. While in principle it should be possible to integrate weather radar information from separate weather radars onto an air traffic radar screen, integration attempts of this sort have generally been unsuccessful and are not recommended.

Most modern, made-to-purpose, weather radars are now Doppler radars capable of measuring the radial velocities of precipitation particles towards or away from the radar. Some sensitive radars, particularly long wavelength S-band radars, are able to detect clear air returns and air motions in the boundary-layer.

High quality weather radars are very expensive and, although not required under ICAO standards, provide valuable weather monitoring capabilities to enhance aviation safety and efficiency. Weather radars require a major commitment of financial and staff resources.

Weather radars generally have a maximum range of about 400 km, but aside from some bending of the radar beam because of atmospheric refraction, the radars are "line-of-sight" instruments and are limited by earth curvature. At longer ranges radars increasingly do not see the lower portions of storms. For Doppler analysis there is a more restrictive range limit of about 250 km. In both cases, terrain obstructions such as nearby hills and mountains can severely limit the area that can be monitored by a radar. In Colombia, terrain obstructions will often be a major problem and would make it very difficult to design a national network of weather radars that would give comprehensive coverage of the national airspace.

EarthSat Recommendation: To gain experience with modern weather radars we recommend that Colombia consider acquiring one Doppler weather radar during the current 10-year planning period to monitor the terminal approach and departure areas for Bogotá's El Dorado Airport. Properly sited and with the necessary software, this radar can also provide operational warnings of convectively-induced windshear and microbursts that would affect aircraft that are landing or taking off. With a successful installation of this terminal area weather radar, additional weather radars could be introduced at other critical airports in Colombia in the years following 2014.

General Specifications: For high quality observations the standard meteorological antenna beamwidth is 1 degree (half-power, full beam width), with a circularly symmetric pencil beam. For long ranges weather detection and for penetration of intense storms, high-power S-band radars are preferred. S-band radars, however, require very large, expensive antennas. For terminal area operations, a shorter wavelength C-band system with lower peak transmitted power – but still with a 1 degree beam – are a good compromise. Shorter wavelength systems such as X-band are not recommended because of attenuation.

The three main types of radar transmitters are klystron, magnetron, and traveling wave tube (TWT). For maximum power and good performance in high-clutter environments such as mountainous areas or urban airport environment, klystron transmitters are usually preferred. TWT transmitters also provide good clutter rejection, but are available only in lower-powered systems that limit the radar's effective range and leave the system subject to attenuation problems in heavy rainfall. Pulse compression techniques can be used to increase the effective transmitted power, but with a loss in range resolution (range side lobes)

A radar's meteorological signal processing, displays, and weather products are a critical aspects of an operational system. Different radar vendors often have processing capabilities and product suites that vary in their comprehensiveness and quality. Furthermore, there has been a history of instability in the providers of weather radar systems, with companies entering and leaving the market, leaving orphaned systems without support. One way to compensate for these potential problems is to specify a specific processing package and product suite in the RFP. Sigmet, Incorporated, has a 25 year history of providing processing systems and meteorological products through their IRIS software packages (see Figures 4.6 and 4.7). Sigmet processors and software are supplied with systems from a number of leading vendors and most weather radar suppliers can supply a radar with Sigmet systems and software if it is specified in the procurement documents. Including a requirement for Sigmet IRIS/Radar and IRIS/Display as well as the Sigmet RVP8 digital receiver and signal processor as part of the technical specification would ensure that all the potential vendors are bidding comparable, high-quality systems within the framework of an open, competitive procurement process.

In summary, we recommend a 1 degree beam, C-band, klystron Doppler radar (250 kw peak power, or greater), with Sigmet processing systems and IRIS product generation software. Recently, Belgocontrol purchased a radar conforming to these general specifications for their airport in Brussels, Belgium (see Figure 4.8).

Radar Location: In order for a weather radar to be able to provide good coverage over the airport and the approach and departure areas the radar should be located in an off-airport location. The radar will need a small tower to elevate it above any local obstructions and for the safety of nearby personnel. An ideal site will be relatively level, with clear horizons in all directions. In order to limit hazardous exposure to microwave radiation and to preserve the clear horizon, there may be a need to limit new construction or impose height restrictions on new construction within several kilometers of the radar. Nearby hills or mountains can significantly limit the field of view. Mountain-top locations are not preferred for weather radars, particularly so for terminal area radars. Such an elevated site would eliminate the low level observations over the airport runways and approach corridors that are necessary for windshear detection and contaminate the signal with extensive ground return that is difficult to remove without also removing the weather signals. For windshear detection the radar should be located between 10 and 20 km from the airport, roughly along the extended axis of the main runways. It may be difficult to find a suitable radar site in the Bogotá area.

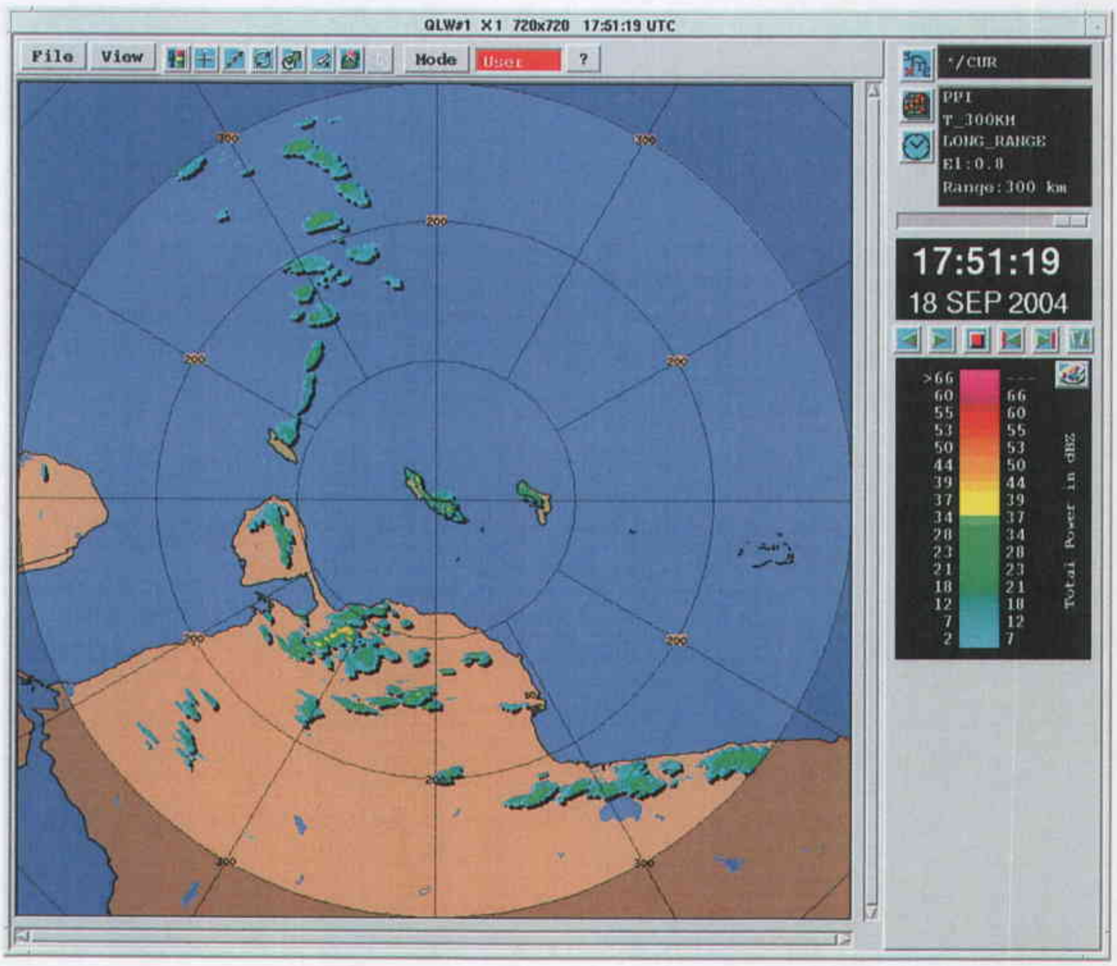


Figure 4.6: Sigmet IRIS radar display from refurbished EEC weather radar system in Curacao (Netherlands Antilles), with radar coverage reaching the tip of Colombia's Guajira Peninsula at the left of the display.

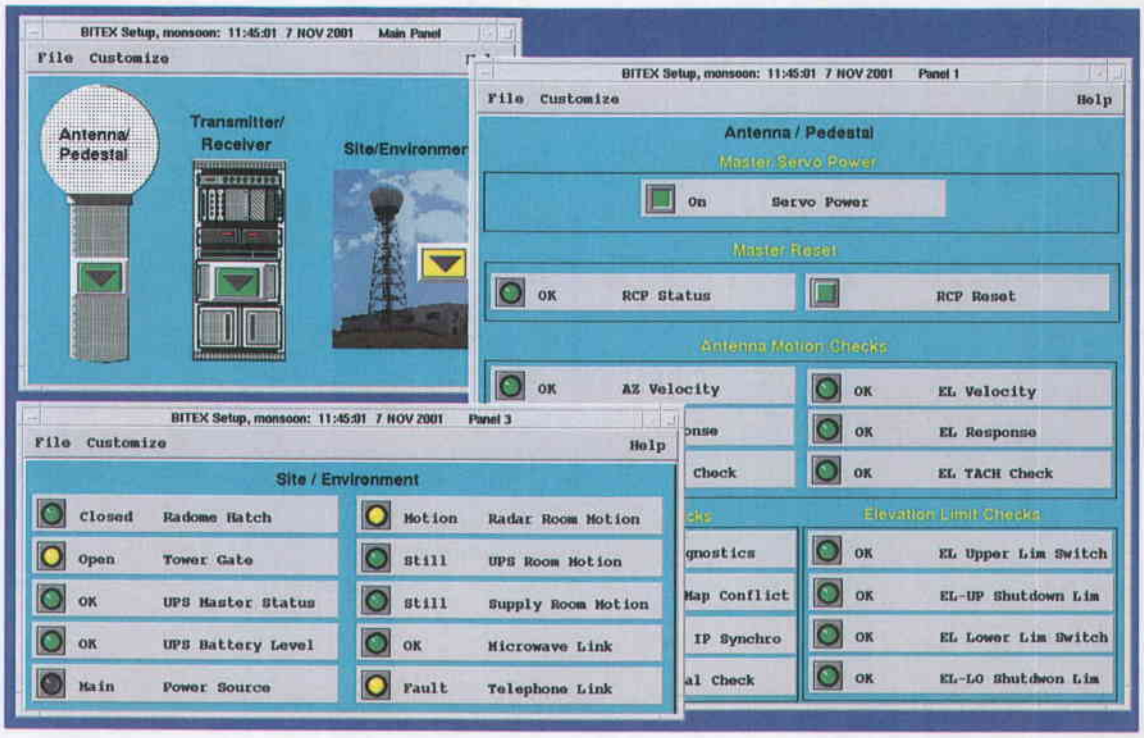


Figure 4.7: Sigmet display showing graphical interface for remote monitoring of their radar system built-in test equipment (BITE).

Figure 4.8: Doppler weather radar being installed in Brussels, Belgium. This is a C-band, klystron system with a one degree beam 4.3 meter offset feed antenna (photograph courtesy of Radtec Engineering).

Approximate Acquisition Cost (for planning purposes): US$ 2.5-3.0 million.
Note that the above system acquisition cost estimate does not include local infrastructure such as a building to house the radar, tower, radome, communication links for data transmission (typically a dedicated T-1 line), land acquisition costs or other factors that are hard to estimate in advance. These additional costs could be quite large, certainly many hundreds of thousands of US dollars.

Doppler radars are sophisticated observational systems and require a significant maintenance budget. A full software support agreement, including phone and e-mail consultation and assistance, might cost US$ 10,000 per year. Over the long term, there will be a need to have a continuing annual support budget that averages at least 10% of the overall original system cost. In some years this will not all be needed, but the allocation should be maintained and reserved for future repairs or enhancements that would otherwise exceed any normally available discretionary funds.

Training: Any acquisition of a weather radar must be accompanied by an aggressive program of training and preparation. As a minimum, two meteorologists should receive extended specialist training in radar operations and use, while at least one engineer receives specific training in weather radar systems and processing techniques. This training may incorporate extended visits to operational radar facilities in other countries or special training programs provided in Colombia through the use outside consultants.

Acquisition Schedule: Acquisition of a radar system is a relatively slow procedure taking several years. Specially, we recommend that UAEAC consider a schedule such as:

Year 1. Hire a consultant for site identification and assistance with procurement technical specifications (working with MET and engineering staff to familiarize them with preferred design requirements). Identify meteorological and engineering staff for training.
Year 2. Issue RFP and select vendor. Acquire site property and begin planning for power and communication services to the site. Begin training of selected staff
Year 3. Installation and testing.
Year 4. Initial operation.

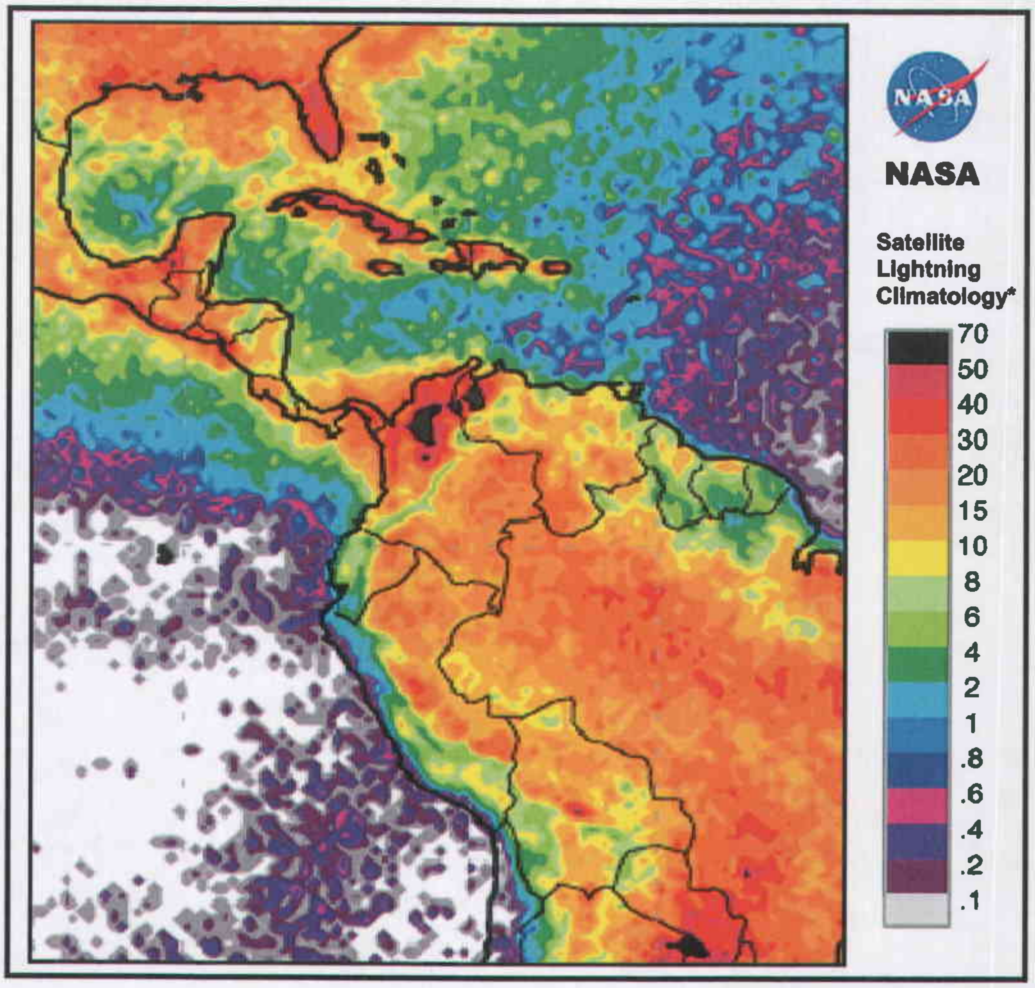
4.8 A national lightning detection network.

Over the past decade the meteorological use of regional networks of lightning detection sensors have been expanding as detection technologies have improved and become standardized. Most of the initial interest in lightning detection was motivated by the operational needs of power companies to monitor cloud-to-ground lightning strikes that can affect their power grid. This lightning strike data has also proved valuable to meteorologists for monitoring the location, movement, and strength of convective storms. These early systems, however, were only able to detect the main cloud-to-ground strikes.

Since lightning is strongly correlated with updraft strength, lightning mapping systems can be used to identify the most severe regions of a storm, the very regions that are most dangerous for aircraft. Lightning detection systems are particularly attractive for use in Colombia since satellite-based lightning climatologies (see Figure 4.9) demonstrate that Colombia has a very high concentration of lighting strikes. Lightning strike data can be integrated with satellite imagery to show the overall cloud patterns while simultaneously identifying the main convectively active regions within the broader storm structure, similar to what can be done with a vastly more expensive network of meteorological radars. In an aviation meteorology application, lightning data can help improve the accuracy of terminal area forecasts (TAFs), help ATC personnel anticipate airport closures, and identify the most severe areas of convective storms for issuing SIGMETs.

Colombia currently has two small networks of cloud-to-ground lightning detectors, one installed by Interconexión Eléctricia S.A. (ISA) and a more limited system operated by a regional power company in Medellín (EEPPM). We understand that these power companies are considering upgrading their cloud-to-ground systems to current standards and may add additional sensors. This offers a unique opportunity for UAEAC to work with these power systems and other potential participants to develop a national network of lightning detection. The full cost of a national lightning detection network would be about the same as a single Doppler radar. With no moving parts, passive sensors, low power requirements, and relatively unobtrusive installations, a high-quality lightning network should be highly reliable with relatively low maintenance costs.

EarthSat Recommendation: We recommend that UAEAC negotiate an agreement with ISA, EEPPM, and other interested federal agencies or private companies to develop a national lightning detection network. With its nation-wide responsibility to provide meteorological support for aviation activities, UAEAC is an appropriate agency to take the lead in this initiative, although IDEAM may also wish to participate in this effort. Other possible participants might include the Colombian Air Force (FAC), the El Cerrejón coal mine, and major oil and petroleum pipeline companies. Each group participating could purchase, install, operate, and maintain their own lightning sensors, but would need to freely share their data as part of a national network. In return for sharing their data, each participant could receive access to the full network products.



Flashes per square kilometer per year

Figure 4.9: NASA satellite climatology of total lightning (cloud-to-cloud and cloud-to-ground) as flashes per square kilometer per year. The gridded lightning data used to generate this figure were produced by the NASA LIS/OTD Science Team (Principal Investigator Hugh Christian, Marshall Space Flight Center).

Roughly 30-32 stations will be needed for full national coverage. If the national network is designed in collaboration with ISA, only 25 additional sensors would be required. We anticipate that the bulk of the new systems will be able to be installed at airports.

The system processing and network data integration could be done in a centralized control room at UAEAC, but ISA may also wish to maintain their own existing Control Room with parallel processing of the incoming data.

Equipment Costs: Approximately US$ 100,000 per site. Civil works and installation would typically run US$ 10,000 per site. The central processing station would cost approximately US$ 400,000. The sensors themselves use very little power, but associated cooling and blowers will generally need access to AC line power. Each remote sensor needs a reliable, medium speed (but low-bandwidth) data path to the central processing station (at least 9600 bps).

Sole Source: Vaisala is the only established commercial supplier of this sort of integrated detection system. In addition to the smaller detection networks installed by Colombian power companies, there are also small Vaisala lightning detection networks in Venezuela and Brazil. With a high-quality national system, Colombia could become the center of a regional lightning network.

Training: While there would have to be considerable operator and maintenance training, lightning data is easy to understand and can be integrated into forecasting and pilot briefing materials without extensive user training. As with meteorological satellite systems and weather radars, it is imperative that selected MET staff members receive specialized scientific training to act as scientific officers with expertise in one of these sophisticated, new observing systems.

Acquisition Schedule: (3 year acquisition plan, plus 1 year of preparation)

Year 1: Design system, negotiate interagency agreements, conduct site surveys, and identify funding.
Year 2: Procure system, install command center and install 5 sensors in locations that can enlarge and expand the existing ISA detection network. Estimated cost for Year 2 – US$ 1 M.
Year 3: Install 10 systems. Estimated cost for Year 3 – US$ 1.2 M.
Year 4: Install 10 systems. Estimated cost for Year 4 – US$ 1.2 M.
Year 5: Completion of the national network, if not already completed.

4.9 Windshear detection & warning systems.

A number of Colombian airports are known to be troubled by strong winds, turbulence, and windshear. Strong, gusty winds are recognized as a problem at Cartagena and Barranquilla on the north coast, and at Leticia in Amazonas. Cúcuta and Bucaramanga also report problems with strong winds and turbulence around the airport. Providencia appears to have wind problems combining the effects of the ocean breeze with hilly terrain around the airport. Pasto, however, seems to be the airport that is most severely impacted by winds and turbulence that appear to be terrain induced.

While there are a number of windshear and turbulence detection technologies, it is essential to understand exactly what is happening meteorologically before installing detection equipment. Most commercial windshear detection systems, such as LLWAS (Low Level Windshear Alert System) and TDWR (Terminal Doppler Weather Radar) are designed to alert tower controllers to specific wind patterns associated with convectively induced windshear, where a descending current spreads out as it reaches ground level and creates a systematic pattern headwinds, quickly followed by tailwinds that can cause aircraft in their final approach for landing to crash. While LLWAS systems have proved to be very valuable in protecting aircraft from convectively induced windshear, they would be of little use in situations of extreme, random turbulence.

Winds that vary with altitude can be monitored effectively with a microwave wind profiler, but the system has a rather slow update rate that isn't appropriate for rapidly changing wind patterns.

Doppler lidars can observe the motion patterns in the turbulent clear air, but except for using the TDWR windshear divergence algorithms on the lidar data sets, these systems do not yet have an automatic warning system and need a qualified observer to monitor the system during turbulence events.

The key issue is to understand the problem. This can be very difficult. At two airports with serious terrain induced windshear and turbulence problems (Juneau and Hong Kong) weather researchers conducted years of study before developing custom systems to identify hazardous areas and warn aircraft or adjust their approach paths to minimize the problem.

Most of the windshear and turbulence problems described to us during our visits to Colombia seem to be terrain induced. This means that the major commercial windshear detection system, such as LLWAS would not be appropriate. It should also be noted that an LLWAS system requires an extensive network of anemometers with strict positioning requirements surrounding the airport out to 2 or 3 miles from the end of the runway. In many of Colombia's most problematic airports it would be very difficult to install a true LLWAS system.

One option that may be appropriate for Colombian airports with windshear and turbulence problems would be to install an extended network of anemometers along the runway and at critical terrain features surrounding the airport. While not a LLWAS system, the anemometers can help monitor the surface wind environment around and near the airport. With experience, local meteorologists and tower controllers may be able to understand which wind patterns and weather condition present the most serious hazards.

After a number of years of monitoring the winds around the airport at Juneau, NCAR scientists devised a prototype operational system that displays an extensive set of wind information, from both anemometers and wind profilers on a single screen, along with the runway head winds and cross winds, along with a graphical summary of the condition and an indication of which approach patterns should be used and which should be avoided (see Figure 4.10). Figure 4.11 shows a somewhat simpler custom display of wind observations from six different anemometers along the runways in Hong Kong.

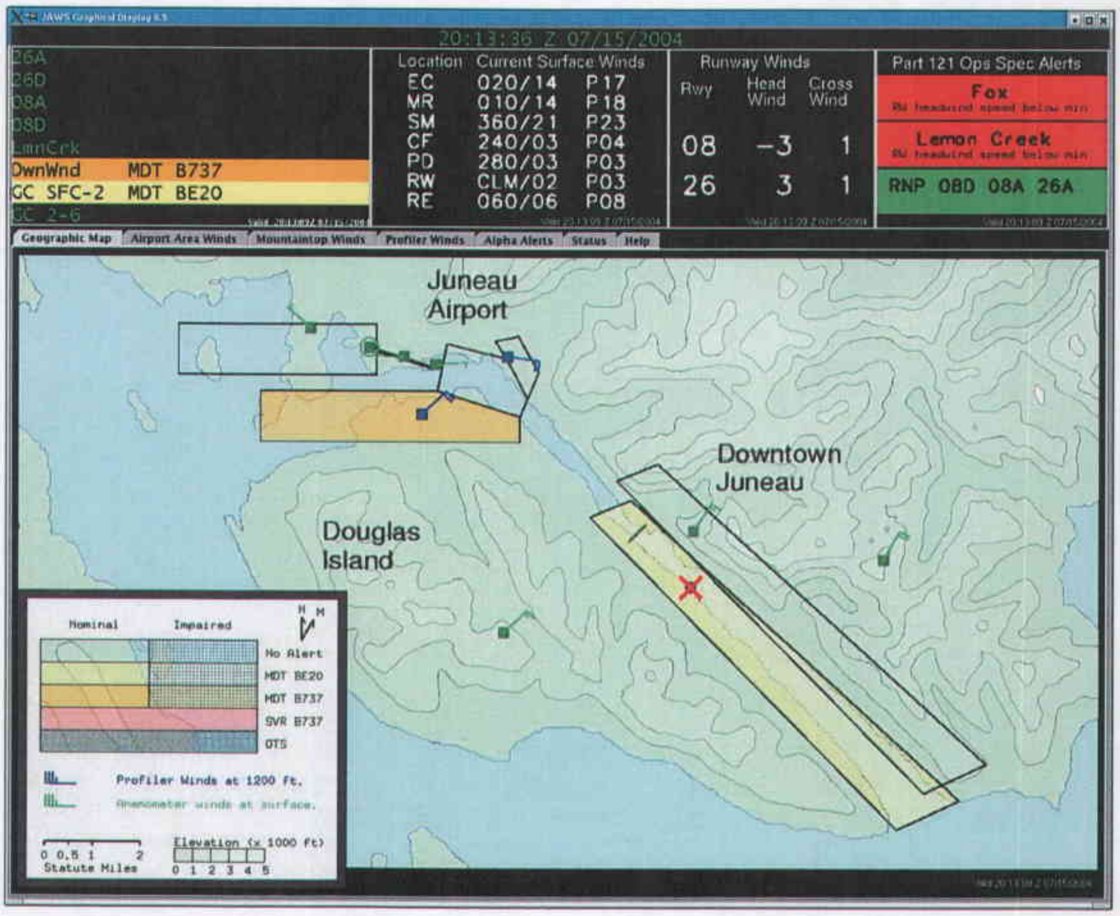


Figure 4.10: A prototype ATC graphical operational display illustrating the complex terrain around Juneau, Alaska, with a large variety of display wind observations from anemometers and wind profilers.

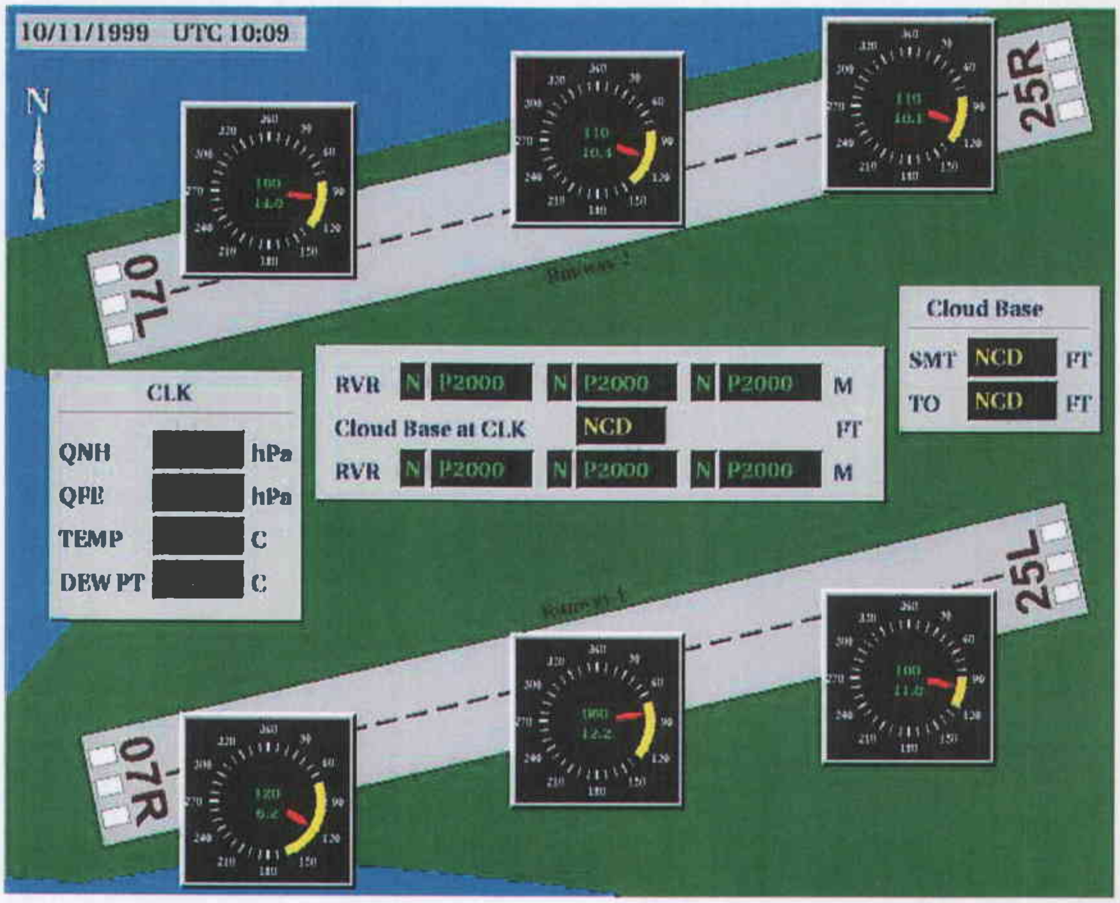


Figure 4.11: A custom airport anemometer display from Hong Kong (illustration courtesy of Hong Kong Observatory).

For monitoring complex winds along the coastline or on islands, it is possible to install anemometers on offshore buoys, such as the Hong Kong example shown in Figure 4.12 (see ICAO, 2004). This technique may prove useful in Providencia.

Another way to monitor winds is through the use of a tethersonde – essentially a small wind sensor that is carried below an inflated balloon tethered by a strong line which can be used to raise and lower the wind sensor (see Figure 4.13). These are versatile systems, but are limited to operation in low or moderate wind situations (winds below 15 m/sec).

EarthSat recommends that UAEAC respond to the call for installing windshear systems at Pasto and other Colombian airports through the installation of a

Figure 4.12: An anemometer being installed on a large buoy immediately offshore from Hong Kong's International Airport.

Figure 4.13: A tethersonde balloon being launched as part of a study of low level wind patterns on the Island of Hawaii

custom surface weather and wind monitoring system consisting of a central automatic weather station with at least three anemometers along the runway, augmented by perhaps four or more additional anemometers installed at critical terrain features away from the airport property. This sort of installation is not a standard commercial product and will require customization for this application, including custom wind displays so that tower and meteorological personnel can monitor the complex wind environment around the airport. Vendors, such as Almos and Vaisala, who also manufacture LLWAS systems may be able to adapt their graphical LLWAS displays for this multi-anemometer installation.

In addition, EarthSat recommends that UAEAC acquire a single tethersonde system for conducting special studies of the wind patterns around Pasto and other airports with terrain induced turbulence and windshear problems. This system would be used to help understand the complex wind environments around these airports and can be moved from airport to airport. This system would not be part of an operational airport system.

Potential Vendors:

Commercial LLWAS systems are currently available from three different vendors who have licensed the FAA-developed technologies: Almos, Vaisala, and Vitrociset. For typical airports a LLWAS system would be expected to cost approximately US$ 1 million, dependent on the size of the airport and area covered. Radar based detection technologies, such as the custom designed TDWR or standard Doppler radars running windshear detection software are even more expensive (see Section 4.7). As noted earlier, these off-the-shelf technologies are not an appropriate solution to the terrain-induced problem that is believed to be the issue at the airports at issue.

Boundary-layer wind profilers can be used to monitor the vertical structure of the horizontal wind looking straight up from a single, installed position. The most commonly used commercial wind profilers are made by Vaisala and cost about US$ 350,000.

Doppler lidars are a relatively new operational technology for monitoring air motions and turbulence around airports. So far, only one Doppler lidar – manufactured by CLR Photonics – is being used operationally for monitoring the airport wind environment, in this case at Hong Kong's new international airport at Chep Lap Kok. Doppler lidars are expensive, starting around 1.5 million US dollars.

Custom installation of multiple anemometers, both on and off the airport property, should be able to be provided by a number of vendors of standard airport surface observing systems, such as Vaisala, All Weather, and Almos and may be available on a custom basis from Coastal Environmental Systems and Sutron. The addition of additional wind sensors and custom displays can be expected to raise the cost of an airport installation of this sort to something like US$ 250,000 (including a standard, full-featured AWOS equivalent system at the heart of the airport weather system).

Vaisala manufacturers tethersonde systems for monitoring vertical temperature profiles and winds up to altitudes of 1 km. A complete, reusable tethersonde system should be available for about US$ 80-100,000.

Proposed schedule and acquisition costs: Reflecting UAEAC's commitment to try to provide a turbulence and windshear shear for Pasto and several other airports, we recommend UAEAC acquire three custom multi-anemometer wind monitoring systems for an estimated cost of about US$ 250,000 per airport. For that price, each of these systems should include a complete, new AWOS-3 equivalent automatic airport weather station as a core component of the system. These systems will most effective if scientific consultants are contracted to help design the installation and customize it for each airport at an estimated cost in the range of US$ 50,000 – 100,000 per airport, depending on the complexity of the airport situation and the degree of testing and evaluation required. We recommend that these systems be installed with at least two years between installations to allow time to evaluate each system before moving ahead with another installation. We also recommend adding a complete, portable, tethersonde system as a temporary additional wind monitoring system that can be moved from airport to airport as required.

4.10 Processing and distribution of real-time observations.

Currently, data collection and distribution are labor intensive activities requiring multiple manual entries of data or reports into separate workstations or communication ports. For efficiency and reliability, EarthSat recommends that Colombia upgrade its observation and data distribution systems to make greater use of a networked communication environment. With the anticipated consolidation of all airport observing systems under UAEAC, the meteorology offices should be fully integrated into the existing airport communication systems.

The automatic transmission of METARs may require a substantial upgrade and modernization of the existing Colombian AFTN system. At present, AFTN data entry terminals are available at most, but not all, controlled airports. Data entry is currently performed manually, by trained, human operators. The future system that we are proposing will require a standard, secure airport network connection that would link directly to the Colombian AFTN system. With a networked interface to the AFTN there will be a number of options for its reorganization and modernization consistent with the ICAO/SAM REDDIG initiative.

Similarly, with networked access to the Colombian OPMET data bank, METARs and TAFs will be readily available in electronic form at all supported airports.

We anticipate that the new, automated weather stations being installed at each controlled airport (see Section 4.1) will be equipped with modern personal computers or workstations as a central element and that these systems need to be configured to transmit METARs automatically. To do this the AWOS computer would have to be connected to a secure, internal airport network with access to the AFTN. There will, however, be an opportunity for tower personnel or trained weather observers to add additional comments to the automatically generated METAR before transmission. AWOS units manufactured by U.S. vendors and certified by the U.S. FAA all have communication ports that enable the digital electronic transmission of the weather observations and METARs.

We anticipate that a second workstation or personal computer would also be connected to the secure, internal airport communication network with access to information from the OPMET data bank and other weather data resources. This workstation will provide access to basic weather information (METARs, TAFs, and image format satellite imagery – at the minimum) and be able to prepare and display local pilot briefing materials. With suitable firewall protection, this workstation would be configured to be able to link to the external public internet for access to publicly available weather information resources. We anticipate that this briefing workstation will grow into a sophisticated system that can be used for MET staff conducted briefings, or configured to support stand-alone user-controlled briefings (see Section 4.15).

Radiosonde stations will also need a secure data link for the transmission of processed soundings to IDEAM and UAEAC forecast centers. IDEAM has the responsibility to transmit the sounding to Washington over the IDEAM's WAFS uplink for entry into the Global Telecommunication System (GTS) for international distribution. With an upgrade to the most recent generation of radiosonde processing systems (see Section 4.5), the radiosonde processing computer will be able to connect directly to the network for easy transmission of the processed soundings. In most cases, however, we expect that radiosonde processing will continue to be performed on stand-alone, independent systems (e.g. Vaisala's MW15) that do not have network connection capabilities. For those sites we recommend that a relatively low-end, networked personal computer or workstation be installed adjacent to the radiosonde processing system. The two computers could then be connected by a simple RS232 serial cable, or a data disk with the processed sounding could be used to transfer the sounding to the networked computer for rapid dissemination.

Estimated upgrade costs for networked data distribution: Most of the costs for the proposed networking upgrades will be associated with the required upgrades to the national AFTN system, as already proposed in the ISI report (ISI, 2003). Detailed recommendations for possible AFTN upgrades are outside of the direct scope of our consultancy.

Within the airport weather office environment, the costs should be limited to upgrading the airport weather computer systems and connecting them to a local network. Each controlled airport will require one, and on occasion two, new computers for an estimated average cost of about US$ 6,000 per airport.

These new, airport weather office networked computers should be introduced on a schedule paralleling the 10-year AWOS enhancements. In order to be able to maintain the networked weather office computers, however, it will be necessary to upgrade and replace the basic system hardware and software on about a 3-year cycle.

4.11 Data integration workstations for forecasting and aeronautical climatology studies

Modern weather forecasting is increasingly being done using computer workstations to display and analyze the weather. These workstations integrate the available observations, numerical model results, satellite imagery, and other available resources with capabilities to overlay different data sets and perform time animations. In the workstation environment the emphasis is on graphical analysis for easy visualization of the overall weather situation. Figure 4.14 shows a dual-screen forecasters workstation being used in Brussels, Belgium, with a graphics window on the right and a text window on the left.

At present, most of the weather data available to Colombian forecasters are provided by the international WAFS data transmissions combined with local observations that are not transmitted internationally, and basic satellite imagery.

One of the most critical current needs is to provide forecasters with full access to all Colombian upper-air soundings and suitable software for analyzing the soundings.

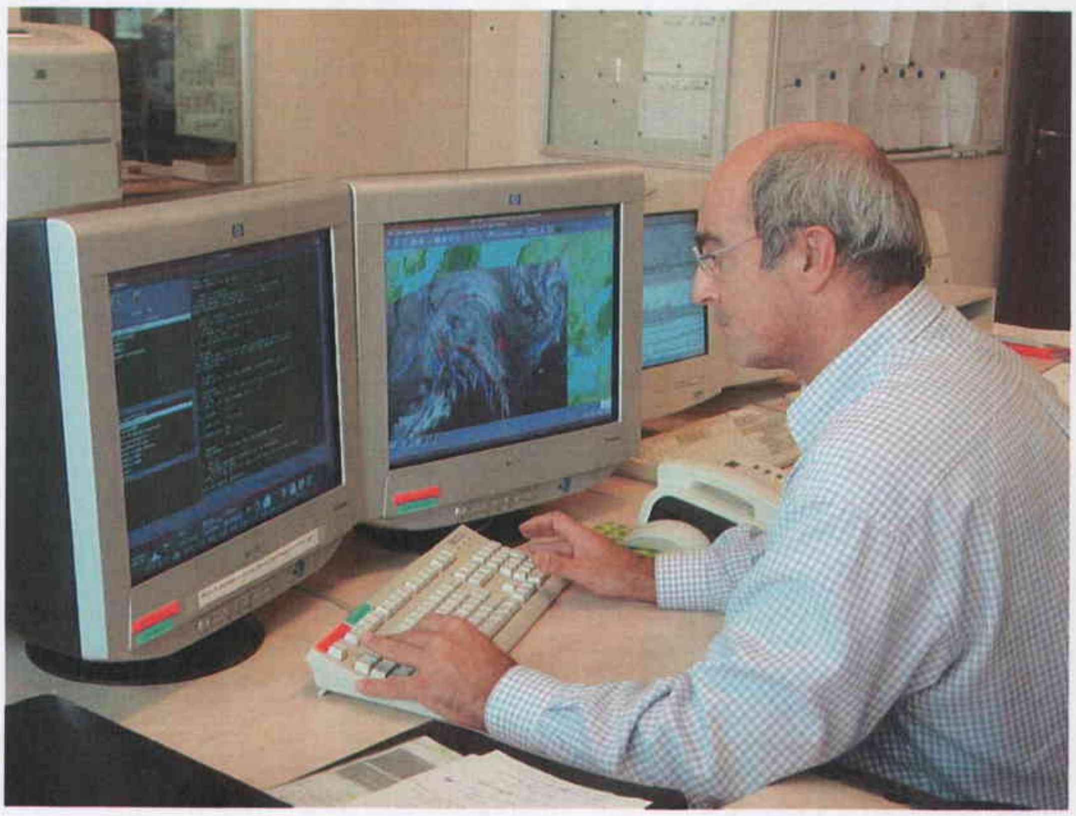


Figure 4.14. A dual-screen forecasters' workstation at use in Brussels (illustration courtesy of Belgocontrol).

At a basic level, a simple or enhanced commercial WAFS workstation may provide significant data integration and display capabilities. Some commercial WAFS systems are even able to enhance the WAFS data sets with locally acquired satellite data or other data sets (see Section 4.13).

More sophisticated systems are usually developed as custom packages that depend on specific, locally-available data sets. The critical factors for these advanced systems is data access, ingest, and quality control. Higher resolution model data fields may be available, sometimes from locally run mesoscale models (see Section 4.14). Other typical enhancements include multi-spectral satellite imagery, weather radar data, and output from lightning detection systems. At this level, data integration becomes the most critical system issue because of the wide variety of data sets and formats that need to be combined into a single analysis environment.

For a custom system, it may make sense to combine the procurements for individual observing systems, such as satellite data acquisition with a contract to provide an advanced forecasters' workstation, including the customization, development, and installation of the complete system. This would allow the system integrator greater freedom to select component systems for quality and ease of integration. In some cases, an individual system integrator may have already developed the processing software and handling systems for specific data sources and formats, allowing them to provide a system at a significantly reduced price. Otherwise, the data integration costs can be major, dwarfing the cost differences between components provided by different suppliers.

With a custom development, the cost is primarily in the software development and the finished product can usually be installed in as many workstations as desired. On the other hand, forecasters' workstations that are standard commercial products are normally sold as a hardware/software package with software limited to a single installation.

One high priority feature that we recommend be incorporated in a custom forecaster's workstation is access to full resolution model output fields (typically 1 degree resolution). Model fields distributed through WAFS are reduced in resolution to shrink the sizes of the files that have to be downloaded. With full resolution data fields, the forecaster can zoom in on the geographical areas of direct concern and see more detail than is available on the standard WAFS transmissions. If a high-speed broadband Internet connection is available, the full resolution model fields can be downloaded over the Internet. Otherwise, it may be possible to access the data via a dedicated satellite communication link.

Any forecasters' workstation should include a full range of graphical thermodynamic diagrams and analysis tools for upper-air analysis. In most cases, three-dimensional model data fields can also be processed to generate synthetic soundings that can be used to examine the vertical stability at arbitrary positions of interest.

The workstation should be able to display surface observations in both a graphical (station model) representation on a background map and as time-series plots of individual parameters from any selected observation station. Full resolution satellite imagery and model output fields should be able to be displayed in user-specified formats, permit other data sets to be overlaid on the background image, and display time animations.

As another component of a full-featured forecasters' custom workstation, background processing routines could be used to assemble routine climate records and reports. Similarly, software templates for common forecasters' tasks, such as SIGMETs and AIREPs could be used to assist the forecaster with these critical, time-sensitive responsibilities (see Section 4.12).

Forecasters' workstations can be used for pre-flight briefing, but would not be available at all airports and are not generally optimized for presenting briefings. A better way to produce advanced products and graphical displays for pilot briefing would be to export the processed data sets and derived products to a separate server designed to support pre-flight briefings through product generation and network connections to local display stations at designated airports (see Section 4.15).

Potential Vendors: Development of forecasters' workstations is a major data integration and development project, but one that has been done many times around the world. There are a large number of potential developers, ranging from contractors who can provide basic, stock solutions to sophisticated and experienced groups who have designed systems of this sort for many users.

It is much harder to develop realistic cost estimates for this sort of project. Depending on the proposed system capabilities and the experience of the vendor, costs could range from as low as US$100,000 to US$ one million or more. Before undertaking a procurement, we recommend that Colombia issue a "request for information" (RFI) asking potential vendors to outline their possible solutions, list references and similar systems already installed, and a preliminary cost estimate. This is a critical component in an upgraded aeronautical meteorology system and it is essential that the possible options be examined carefully. As part of the investigation of potential approaches we recommend that a team of UAEAC staff and experienced forecasters visit several of the potential vendors or travel to locations where they can observe and examine installed, operational systems. With that information UAEAC could then go ahead with a competitive procurement for a clearly defined system and realistic target price.

4.12 Software templates for AIREPs, SIGMETs, and other routine reports.

Preparation of AIREPs and SIGMETs can be time-consuming and difficult. To encourage aviation forecasters to issue these reports it is important to conduct regular training for procedures and standards, and to make the preparation of these reports as easy as possible. One way to do this is to provide computer-assisted software templates that help format the reports and get them ready to transmit. Stock phrases can be pre-programmed and entered into the report with the click of a mouse. Times and dates can be entered automatically. In a sophisticated system, locations could be identified by the click of a mouse on a computerized aviation map or current satellite image.

Increasingly AIREPs, SIGMETs, TAFs, and METARs are being scanned and decoded by automatic systems. In this case, a simple typographal or entry error can render the reports and warnings useless and unread. One way to remedy this problem is to add an additional automatic message scanning and review step before these reports are transmitted. In other words, run the reports through an automatic decoder to ensure that the reports are machine readable. Any errors that are discovered can be flagged and displayed for manual corrections by the duty forecaster or observer. When applied to automatically generated reports, such as METARs generated by a fully-automatic weather station, this sort of final filter can serve as an additional test of the adequacy of the system software that was used to prepare the reports.

Templates of this sort should be considered as an essential part of a weather data integration and forecasters' workstation (see Section 4.11), but could also be run as a stand-alone application. If not included as a standard feature in the forecasters' workstation, custom templates should be able to be prepared by many of the same potential system vendors who are qualified to provide forecasters' workstations. Basic text-based templates with a graphical interface for data entry should be available as a custom development for under US$ 100,000, while adding interactive graphical data displays could double the cost.

EarthSat strongly recommends that Colombia include software templates of this sort as part of a comprehensive forecasters' workstation.

4.13 Accessing WAFS data sets.

The World Area Forecast System (WAFS) is a program developed by ICAO and the WMO to improve the quality and consistency of en-route weather guidance provided for international aircraft operations. Currently, aviation model forecast products in a standard gridded format (GRIB) and well as graphical products such as en-route wind and temperature forecasts and significant weather charts are prepared at two World Area Forecast Centers (Washington and London) and distributed through the International Satellite Communications System (ICSC). Colombia has been provided with a WAFS workstation and two-way VSAT communication link that was donated by the U.S. National Weather Service (NWS). The primary purpose of the WAFS transmissions are to support the worldwide aviation community with operational meteorological forecasts and information about meteorological phenomena required for flight planning and safe, economic, and efficient air navigation. The associated uplink from Colombia to Washington is considered to be part of the RMTN (Regional Main Telecommunication Network) supporting the WMO's GTS (Global Telecommunications System) that provides for the exchange of meteorological data among WMO member states.

The Colombian WAFS system is managed and operated by IDEAM. The system provided to Colombia consists of a 2-way VSAT communication system coupled to a Global Science & Technology (GST) "MetLab" WAFS workstation. The workstation integrates data reception, display, analysis, and can be extended with optional pilot briefing packages. Aviation and weather data received via the WAFS system is sent to the forecast center at El Dorado airport as the primary source of weather information for Colombia's aviation forecasts.

To provide for independent access to WAFS aviation data sets and products, UAEAC has expressed an interest in purchasing their own WAFS workstation and perhaps their own VSAT data link to Washington as well. For compatibility with the existing WAFS workstation at IDEAM, UAEAC may wish to purchase a MetLab workstation from GST. The WAFS workstation could be configured as a stand-alone workstation (without VSAT communications) that could be used to display and analyze data passed on through IDEAM, or could be equipped with its own VSAT communication module to provide independent access to the WAFS data sets.

A VSAT communication module can include a transmission uplink capability, or could be a receive-only system. Adding the uplink capability would provide UAEAC with a full, backup system for the IDEAM installation, although the additional Colombian uplink would have to be approved by the Washington WAFC and Region IV communication specialists and may involve a monthly VSAT usage charge (for uplink systems only).

Approximate pricing for WAFS systems:

A WAFS workstation with VSAT communications (receive only) should be priced in the vicinity of US$ 75,000. Adding an up-link capability would add about $10,000 to the system cost. This system, however, has relatively limited display and analysis capabilities.

An analysis-only WAFS workstation without a VSAT communication link, but with a number of optional analysis, integration, and display capabilities – including a pilot briefing module – would be priced at about US$ 80,000.

Given the fundamental importance of the WAFS data stream to Colombia, we recommend that UAEAC acquire its own WAFS receiving station (receive only) along with a basic WAFS workstation to display the incoming data sets and assemble basic aviation products such as the International Flight Folders.**

As discussed in Section 4.11, an expanded WAFS workstation can also be used as a basic forecasting workstation. EarthSat, however, recommends that UAEAC first explore more sophisticated forecasting workstations that have additional features to assist the forecaster. In this approach, the WAFS workstation is primarily a data portal that can also serve as a backup system for preparing forecasts.

4.14 Numerical weather prediction model development

Numerical weather prediction models are a valuable tool for anticipating future weather trends and are essential for modern weather forecasting. Model output fields can already be received through the ICAO-sponsored WAFS data stream from Washington. These models, which are run at the World Area Forecast Center in Washington D.C., frequently have had difficulties in tropical areas near the equator and have not been heavily used in Colombia.

Part of the difficulty in Colombia is the dramatic influence of terrain, land surface properties, and localized moisture sources. Modern mesoscale numerical models are designed to handle these small-scale, local features and assist the forecaster to make more accurate forecasts. Under most circumstances these models are run locally, but they could also be run by a foreign company or institute.

EarthSat recommends that UAEAC take the lead in a multi-agency collaboration to help develop high-resolution, mesoscale weather prediction models for Colombia and northwestern South America. This collaboration could include FAC, IDEAM, meteorologists at the Universidad Nacional de Colombia in Bogotá, and scientists from foreign institutes where such work is routinely undertaken.

** During the review of this report we learned that UAEAC has purchased a WAFS receiving station (one way) from IPS Meteostar.

In terms of infrastructure, we envision the creation of a local computing center with a large, multi-processor workstation optimized for running numerical models. This computer center will need to have international high-speed Internet access to make use of global model data sets as initialization fields and to access local Colombia weather information from IDEAM and UAEAC.

The initial efforts could be structured as a continuation and enhancement of the current work being done at Universidad Nacional, with participation and support by UAEAC, FAC, IDEAM, and foreign scientists. The major new acquisition needed to support this model development effort will be a multi-processor modeling cluster with supercomputer-class performance. Based on current requirements and available hardware we recommend a 32-node cluster, including a large RAID data storage system and high-speed inter-node networking. An implementation of MM5 or the new WRF running in a nested-grid mode on such a platform should be able model the local weather environment on a spatial scale of 2-4 km making use of high-resolution terrain maps and land-surface characteristics, augmented by local meteorological observations such as METARs.

Exclusive of staff salaries, we estimate a 4-year start-up budget of US$ 1 million for analysis workstations, communication links, and the multi-processor modeling cluster, followed by a continuing maintenance and software support budget of approximately US$ 100,000 per year. There should also be periodic upgrades and replacements of the cluster components, estimated at US$ 300,000 every three years. Foreign experts in mesoscale modeling should also be involved in this effort at a total additional cost of approximately US$ 200-400,000.

As an alternative, UAEAC could initiate this modeling effort entirely through a private company or independent consultant who could import and customize the basic models and train UAEAC staff how to maintain, support, and use the model. This would be a major effort and require a major commitment, including the hiring of experts in meteorological numerical modeling. This approach would provide an end-capability sooner and more reliably than a Colombian led effort and provide better options for incorporating custom aviation weather products already developed elsewhere. Based on our experience with similar programs in the United States, we recommend a budget of about US$ 1 million in each of the first two years, with an ongoing testing, improvement, and maintenance consultancy at US$ 300,000-500,000 per year for this approach.

4.15 Pre-flight briefing systems

Pre-flight briefings for pilots are a key part of the Colombia's aviation meteorological responsibilities and are required by ICAO. Briefing materials can also be used to assist ATC personnel and airline dispatchers. At present, pre-flight information exchange usually consist of being handed printouts of METARs and a TAF, if available. Pilot briefings and even casual discussion between pilots and airport MET staff appear to be limited to unusual events.

Graphical briefing materials that are custom designed for the task are more effective and have a greater impact. Briefings can be done by trained meteorologists, or by automatic, self-briefing stations. In some case, briefing materials may be made available over the internet for full public access.

The key element in an effective pre-flight briefing system is to have good weather information that is presented in a clear and attractive format. When presented on computer workstations, large format display screens can make the materials easier to see and discuss (see Figure 4.15).

Figure 4.15. A large screen display for weather briefings.

Over the past five years, meteorologists and software engineers at NCAR and NOAA have worked with the (U.S.) Aviation Weather Center to produce a web-based aviation weather information service, called ADDS (Aviation Digital Data Service), which has won numerous awards.

http://adds.aviationweather.gov/

Recently Canada has introduced its own web-based aviation weather information service. In Hong Kong, aviation weather information is provided through a web-based Aviation Meteorological Information Dissemination System (AMIDS) to airlines, as well as through a separate weather summaries and data links. Taiwan has its own restricted-access web-based multi-dimensional display system for aviation weather.

ADDS offers a wide variety of pre-flight briefing tools and products. Many of the data displays and processing options that should be included in a forecasters' workstation (see Section 4.11) are also useful for briefing pilots. The briefing materials should include weather maps – current, historical, and forecast – and model output fields. High resolution satellite imagery, both visible and infrared, is critical for understanding the overall weather pattern and anticipating the movement of weather systems during flight.

One special ADDS tool is the flight path tool which allow a pilot or dispatcher to interactively select (or draw on a map) a particular anticipated flight path and generate depictions of user specified weather data fields in both horizontal plan view and vertical cross-section view (see Figures 4.16 and 4.17).

Individual station observations should be able to be examined graphically and in the form of individual station time series plots to illustrate weather trends. The pilot should be able to see graphical representation of the locations of SIGMETs and special AIREPs, and quickly pull up the text messages for these warning products.

EarthSat recommends that UAEAC make a special effort to develop high-quality briefing products and systems to serve the Colombian aviation community. While there are several approaches to presenting the briefing materials, we are impressed with the capabilities demonstrated by web-based technologies, such as ADDS, and encourage Colombia to explore that options first. ADDS-style systems are well suited to incorporate local forecast models that can generate aviation-specific weather information.

In the Colombian environment, we recommend that the briefing materials be delivered over a secure, internal, airport communication rather than opting for full public access over the Internet. Large data sets, such as satellite imagery, can be "pushed" to the individual briefing workstations from a central server to maintain a fast, responsive briefing environment and to minimize the repeated requests for large datasets.

EarthSat recommends that pre-flight briefing stations be installed at every Colombian controlled airport. Briefing terminals can also be installed at airline dispatch offices and ATC control centers, while remaining under the supervision of UAEAC.

In addition to common weather briefing products, web-based weather information services can be designed to incorporate features such as airport web cameras, rapidly updated weather information from all airports (updates every 5 minutes) that can be used to generate time series plots, and a central data base for airport operational status (see Section 4.17).

Possible vendors and cost estimates:

The development of pre-flight pilot briefing materials can be done by most prospective vendors for the forecasters' workstations, and could be include in a single procurement. Alternatively, a separate procurement could be held for the pre-flight briefing materials and support system. As discussed in Section 4.11, we recommend that UAEAC issue a RFI to help define system capabilities and decide whether the briefing task should be integrated with the forecasters' workstation effort, or conducted separately. For planning purposes, we estimate that a reasonably full-featured update of the ADDS web system could be assembled and customized to Colombian requirements for approximately US$ 250,000 (exclusive of remote airport hardware and communication links). Since the technology is web based, local workstations can be obtained for US$ 2,500 to US$ 5,000

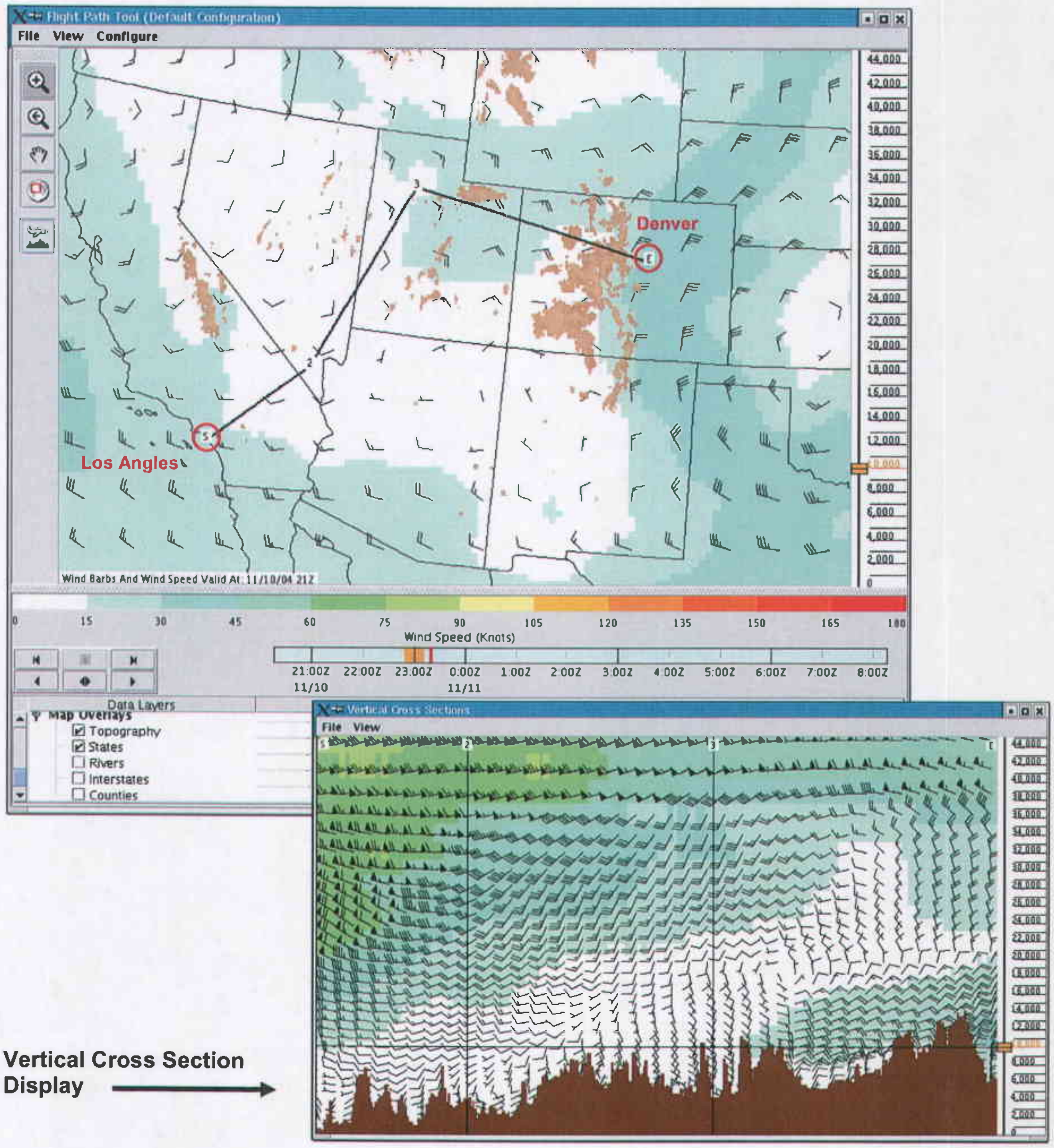


Figure 4.16. An example of the ADDS interactive "flight path" weather information tool. The main window shows the horizontal wind speed and direction for a user-selected flight altitude of 10,000', along with national and state boundaries and terrain areas (in light brown) that reach flight altitude. The user can select an arbitrary flight path (in this case from Los Angles to Devner, via Salt Lake City) which then displays a vertical cross-section of the weather and terrain features along the flight path.

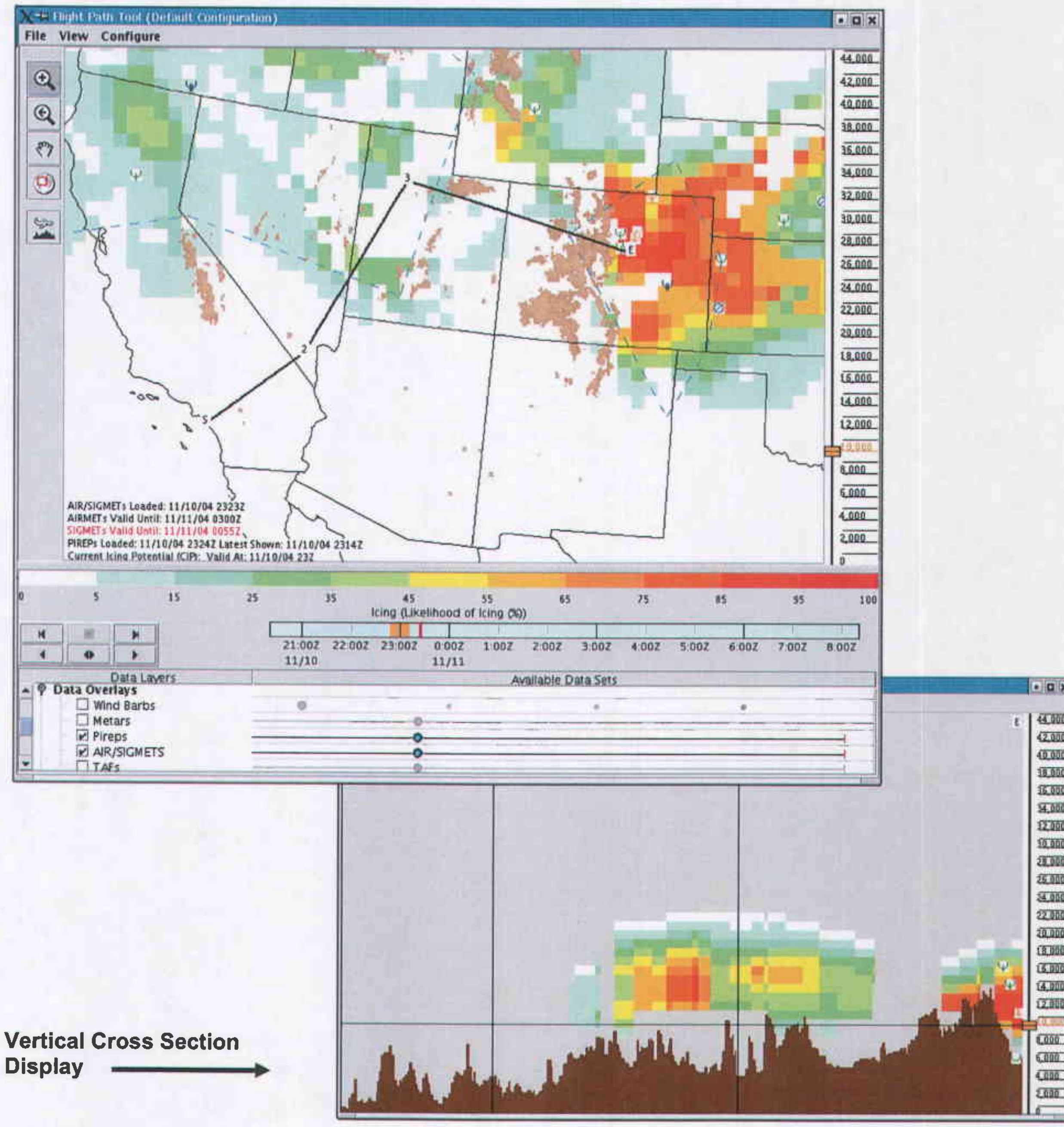


Figure 4.17. Another example of the ADDS "flight path" tool. This display, for the same flight path shown in the previous figure, illustrates a display of a custom in-flight icing product, along with pilot reports (AIREPs), SIGMETs, and AIRMETs. The vertical cross-section shows the areas of dangerous icing in conjunction with the underlying terrain. The data box at the bottom of the main window summarizes the available data sets, many of which can be superimposed on the background data field. The ADDS system also maintains a short term archive of the weather data so it can perform animated displays of the changing weather patterns.

depending on the display requirements. As previously noted above, the graphical presentation of briefing materials is most effective when developed with access to high resolution numerical model output.

Combined with the recommended upgrades to airport weather systems and networking (see Section 4.10) we anticipate a total, per airport, computer systems upgrade cost of about US$ 10,000.

4.16 Communication upgrades

UAEAC has recently completed upgrading many of its communication systems. In developing the current system little provision was made for weather data transmission. In large part, this is merely reflects the current weather observation system which is based on short text messages that do not present any difficulties to even relatively low bandwidth communications.

Our 10-year plan for upgrading Colombia's aviation weather system will dramatically expand weather data transmissions through the expansion in the use of satellite imagery, weather radars, lightning detection networks, numerical weather prediction models, and sophisticated pre-flight briefing workstations at every controlled airport. These new systems may require significant upgrades to the UAEAC communication systems.

Perhaps the most critical improvement needed is to upgrade the AFTN system to allow controlled network access from secure computers and workstation through a modern TCP/IP communication protocol (see Section 4.10). This upgrade would also be consistent with the ongoing ICAO/SAM REDDIG initiative which seeks to transition the system's current serial protocol landline transmissions to satellite-based TCP/IP transmission. Within Colombia the basic AFTN functionality could then be concentrated at a few central sites with service to outlying airports being provided through standard, secure, network communication links. Since the AFTN message traffic would still be text based, this change would not require a major increase in bandwidth or system throughput.

Routine downloading of high-resolution model output files for use in forecasters' workstations and for initializing mesoscale models will require high-speed broadband Internet connections at the UAEAC forecast center at Bogotá's El Dorado airport and at the proposed mesoscale modeling center (see EarthSat Working Paper Number 3). Typical model files are approximately 30 MB in size, with as many as 10 files needing to be downloaded within a 30 minute period, once every six hours.

The provision of modern, pre-flight pilot briefing systems at every Colombian controlled airport, along with additional systems installed at air traffic control centers and airline dispatch offices may mean a significant increase in message traffic over UAEAC's dedicated VSAT and microwave communication links. Most importantly, these communication links need to be extended to every controlled airport (see Table A-3 in

Appendix A). By using a "push" distribution model, the impact on other communication requirements can be minimized, but may still mandate significant system upgrades, particularly at smaller airports that have not yet received upgraded aviation communication links. The most data intensive product expected to be distributed to the pre-flight briefing station would be regional subsets of model data fields and high-resolution satellite imagery. A preliminary estimate of the expected data transfer requirements suggests a need to download about 20 MB within a 5-10 minute period, once every 30 minutes to most airports, and as much as 50-60 MB needing to be "pushed" to Colombia's international airports every 30 minutes to provide comprehensive model and satellite coverage over international air routes.

Increasingly, aviation weather information is being provided to end users through web-based internet systems. International examples include the ADDS weather information system used in the United States and similar systems already in use in Canada and Taiwan.

With Colombia's aviation weather services consolidated within UAEAC, there will also be a need to provide routine, high-speed Internet access to every weather office to provide access to publicly available weather information. These publicly available data sources provide a critical backup to the government-provided services. This sort of web access does not have to be provided through the internal, secure aviation communication links, and can make use of normal public access channels.

Summary of requirements:

- Network connections (TCP/IP) to every controlled airport with a minimum uplink speed of 9600 bps (airport to Bogotá) and a minimum downlink speed of 50 kbps (Bogotá to each individual airport). Higher speed downlink connections would provide better service and more options for airport weather briefing systems (500 kbps preferred). We anticipate that these connections will be provided in the form of a secure AeroCivil intranet.
- Additional data connections to a limited number of uncontrolled airports (see Table A-3) in support of a National Lightning Detection Network (see Section 4.8). A 9600 bps connection is adequate for these systems to communicate with a central hub that will be located in Bogotá). While a number of different options are available, most such systems currently make use of a TCP/IP network link.
- Meteorological workstation will need to be able to link electronically to the AFTN system using a standard TCP/IP network protocol, most likely through secure gateway machines managed by AeroCivil.
- The main, centralized aviation forecasting and modeling centers will need to have broadband (1000 kbps or greater) access to the internet for downloading model datasets and other information over public internet channels.
- For end-user distribution of weather products, AeroCivil will need high-speed web servers capable of supporting the proposed self-service weather briefing workstations (see Section 4.15). These services can be restricted to systems that

can be reached through an AeroCivil intranet, or could be made available to the public over normal internet channels.

Recommended architecture: While it is beyond the scope of this consultancy to propose a detailed system architecture, we anticipate that the required communication and data links can be provided by an expansion of the existing AeroCivil communication systems (VSAT and microwave). Similar communication links could also be provided by commercial providers with satellite-based systems that provide high-speed data distribution to end users and relatively limited uplink capabilities.

Recommended protocols: TCP/IP. This has already become the international standard for data transmission, as reflected in the recent WAFS system upgrades and the ongoing ICAO/SAM REDDIG initiative. In the United States, most meteorological data sets are now distributed through landline and satellite-based TCP/IP connections.

Estimated costs for upgrading MET communications: It is difficult to estimate the costs for upgrading UAEAC's communication links to provide for the additional capabilities needed to support the enhanced meteorological services and data acquisition. This will require an extensive review of current system capabilities and options for enhancements that is beyond the scope of this consultancy. As a placeholder, however, we have included an annual estimate of US$ 50,000 per year over a ten-year period for these communications upgrades.

Additional future upgrades: While the upgrades described above will provide a very substantial enhancement to UAEAC's communication systems that should be adequate for today's needs, the recent explosion in data networks and communication technologies is changing the way that use communication links. New technologies such as video conferencing and voice over internet protocol (VoIP) are likely to become commonplace in the airport environment, while at the same time that high-resolution output from numerical models, satellite imagery, and Doppler radar data will require ever increasing bandwidth. In the long run this means that Colombia needs to develop a plan to provide high-speed broadband digital network connections to all controlled airports.

4.17 Additional opportunities for monitoring airport operations and weather

In a modern system, weather information consists of more than METARs and TAFs. With the availability of networked, real-time weather data from all Colombian airports it will be possible for a user to see high-resolution time-series plots of basic weather parameters at all Colombian airports. In a typical application, the current airport weather observations could be transmitted to a central site every 5 minutes, with the information from all airports being made available to all users. Time-series plots are a good way to observe changing weather situations and monitor forecast accuracy.

A similar approach could also be used for assembling and disseminating a real-time data base summarizing each airport's operational status. Is the airport open or closed to traffic? Is the closure weather related, or does it reflect other operational constraints? With the availability of a real-time data base of this sort, it would be easy to incorporate the information into the proposed weather briefing workstations for pilots and ATC personnel.

In many areas of the world, web cameras are becoming very popular for monitoring road conditions and weather. Web cameras installed at airports would allow pilots and ATC personnel to actually see the local conditions at a destination airport rather than just depend on numerical products and data summaries. In combination with concise summaries of the airport's current automatic weather observation, web cameras provide a simple, effective way to communicate weather information. This sort of information is immediately understandable and trustworthy and could be made part of pre-flight weather briefing system (see Section 4.15).

En-route aircraft could also be advised on changing conditions by dispatchers or air traffic controllers with access to the camera displays. This sort of system has been very well received in Alaska and is being considered for implementation in mountain passes in Colorado to supplement an existing deployment of AWOS-3 facilities.

The Alaskan system can be assessed through the following web link:

http://akweathercams.faa.gov/#

A similar system is being used in Canada, with the airport web cameras being accessible through a NAVCANADA web portal (click on the "Wx Cams" button):

http://www.flightplanning.navcanada.ca/

Approximate acquisition costs for airport web cameras: Web cameras are widely available and can be obtained with their own direct internet connection. For planning purposes we are suggesting a US$ 4000 per airport, to be installed when each airport's surface weather systems are upgraded.

5 Additional Considerations

5.1 Staff levels and training.

These recommended upgrades to the Colombian aeronautical meteorology system will require significant changes in staff assignments and responsibilities. Some organizational changes will be needed and budgets will have to be adjusted. EarthSat's recommendations for organizational and staffing changes will be presented in Working Paper Number 3.

With the modernization and expansion of the Colombian meteorological observing system and the proposed expansion of forecasting responsibilities, there will be a critical need for expanded meteorological training programs to improve the skills of existing staff so they can advance to higher classifications. It may be beneficial to develop cooperative programs with Colombian universities to ensure that there will be an adequate supply of well-trained meteorologists in future years. Training requirements and budgets will also be discussed in more detail in EarthSat's Working Paper Number 3.

5.2 Procurement procedures.

In broad terms, the goal of a procurement process should be to ensure that the government gets a good value, not just the lowest cost. The equipment being purchased has to be able to perform the desired functions with acceptable accuracy and reliability. This means that it is critical that the procurement documents and technical specifications set strict standards for acceptable equipment, standards that can be demonstrated or documented. The essential step in doing this is to understand the equipment being purchased well enough to be able to identify the specific features that discriminate between unacceptable, lower-quality systems and high-quality reliable systems. In some cases, airport staff may not be able to set these standards on their own.

In preparing for a Request for Proposal (RFP) or Request for Bid (RFB) it may be necessary to visit airports in surrounding countries, examine the systems that they are using, and review their performance history with the system operators. In the United States, the FAA and the U.S. Weather Bureau will generally welcome official visitors and discuss their aviation support systems. The FAA has made a particularly strong effort to test potential observing systems and, in some cases, actually becomes involved in the system design and software development. This puts them in a very good position to help identify the critical features or capabilities that are needed in a particular observing system.

Some vendors identify their products as FAA "certified" or perhaps as meeting FAA specifications. At times this can be misleading. In general, when the FAA purchases a new meteorological system they develop a detailed technical and performance specifications and then test the products offered by potential vendors. While any number of vendors may meet the minimum required standards, only one or two will receive contracts. Most of the time there is no "certification" involved. The FAA sets standards, tests, and then buys systems. Having a weather system used by the FAA is convincing evidence that the system meets high standards. Other vendors' systems might also meet the specifications, but there is usually no formal verification of that, unless the vendor can demonstrate test data of their own. There are, however, a few limited cases where the FAA does certify some specific categories of weather systems.

There are, for example, a large number of airports in the United States that need to buy and install their own weather instrumentation, but aren't in a position to perform their own testing. To assist the operators of these airports, the FAA has created a program to certify automated weather stations (AWOS).

It is important to remember that weather system certifications, when offered by the FAA, are specific to a particular instrument configuration or model number and are not awarded to the company as a whole.

In terms of procurement procedures, asking for either FAA certification or evidence of a particular system being in use by the FAA is a good guarantee of a quality system.

In many cases it can be quite beneficial to hire a consultant who is knowledgeable about a particular instrument or observing system to help prepare a technical specification or to review a specification before it is released. Qualified consultants can also ensure that the technical specifications are consistent with standard features of commercially availably products. Specifying non-standard configurations or unessential enhancements can dramatically increase the tendered prices or cause qualified vendors to decline to bid at all.

At the same time, customized products may be available without significantly impacting the acquisition price. If a customized product or new feature is of interest, it is often useful to issue a "request for information" or RFI to ask potential vendors to outline potential solutions to a particular requirement that can be used to guide the preparation of a final RFP.

One area of particular importance which may justify custom enhancements to standard products is screen format and data displays for use in weather offices or control towers. The prospective operational displays should be reviewed by the ultimate end-users to ensure that the displays are clear and easy to read and will provide all the information that is required for efficient operations.

In many cases system upgrades will have to be introduced gradually over a multi-year period. If this is handled as separate annual procurement packages it is possible to end up with incompatible systems from different vendors that will be difficult to maintain. Many countries get around this by issuing RFPs that specify a guaranteed minimum number of systems that will purchased, while at the same time giving the government an option to purchase additional systems at a comparable price for several more years. This approach often simplifies the procurement process and restricts the number of different systems that have to be maintained. Bulk purchases of the same equipment also result in economies of scale and generate lower unit acquisition costs.

5.3 Maintenance and calibration.

In order for Colombia to have a modern, efficient aeronautical meteorology system it has to develop a better maintenance program for its observation and analysis systems. Routine preventive maintenance can ensure accurate measurements and extend the life of a system. For the most part, each system vendor can provide a recommended schedule of preventative maintenance that includes periodic calibrations and data checks.[††] These activities can be performed by trained government technicians, or by private companies under contract to the government.

As part of a well designed maintenance program, there is also a need to maintain a parallel, independent system to monitor data quality. Weather observers, ATC personnel, and pilots are often quick to recognize faulty weather reports or suspicious data. With a well defined set of procedures, users should be encouraged to report potential problems. In order to resolve conflicts about data quality, the UAEAC maintenance authority should establish a limited meteorological calibration facility with portable, reference quality instruments that can be used to verify the accuracy of operational systems. In particular, UAEAC should have high-quality portable barometers can be used to verify the atmospheric pressure measurements that are used to calculate altimeter settings.

In most cases a good maintenance plan may require an annual budget equal to about 10% of the original purchase price of the equipment that is being maintained. Maintenance activities may include the routine purchase of software support and system maintenance contracts, when available. Thus a new, one million dollar weather system may require a US$ 100,000 annual maintenance and support budget. The actual support budgets, of course, will vary from system to system, with some systems being inherently less expensive to maintain. Well maintained systems will perform better and last longer than systems that are ignored.

General use computer systems, such as personal computers and low-cost PC-based workstations require frequent upgrades to their operating system and software. For these systems it is usually more cost effective to replace the computers on a regular replacement cycle rather than try to perform individual upgrades and enhancements.

Resources for system maintenance and support:

Maintenance and calibration activities require a high-quality set of test and calibration instruments, as well as a full set of calibration tools and equipment provided by the system vendor. In many cases it will be necessary to request additional equipment for calibration and testing beyond systems that are customarily sold with the basic system.

[††] Maintenance procedures should be provided by the original system manufacturers and not a local Colombian agent or company representative.

High quality calibration barometers are available from Coastal Environmental Systems, ParoScientific, and Vaisala. The Coastal Environmental system, in particular, was designed in collaboration with the U.S. Weather Bureau as a portable calibration standard for airport weather stations. Air temperature and dew point measurements can be obtained with a variety of instruments, from traditional sling psychrometers to portable fan aspirated systems.

We also recommend that Colombia purchase one or more complete airport weather systems for use in training and maintenance support.[‡‡] These systems should be installed, in full working order, in Bogotá where they can be monitored, evaluated, and compared with similar systems provided by other vendors. If installed as portable systems, these stations could be temporarily installed along side a questionable station for testing and calibration. If needed, these systems could also be used for parts for emergency repairs at any airport, but should be returned to their role in training and maintenance support as soon as replacement or repair parts are obtained from the original equipment vendor.

5.4 Buildings and space requirements.

Most of the changes and upgrades that EarthSat is proposing can be accomplished without necessarily requiring major changes to space allocations and building requirements. There are, however, some initiatives that will require additional working space.

5.4.1 Airport weather offices.

All controlled airports will need to have weather offices or work areas in a controlled environment suitable for electronic equipment and computers, and served by all needed communication links. The meteorology space should be located at a convenient location for pilot briefing, usually adjacent to airport AIS flight planning services. At most airports these offices would initially be staffed with meteorological observers, but may ultimately be unattended. These offices would normally require about 10-20 m^2 of space, but may be part of a larger shared space with airport AIS personnel.

5.4.2 Aviation forecast center.

As discussed in Working Report Number 3, EarthSat recommends a gradual, but substantial, increase in the number of aviation forecasters to permit TAFs to be prepared for every controlled airport and to support the expansion of other meteorological services. This expansion would most likely be provided through a centralized Bogotá facility. A centralized forecasting facility may well require as

[‡‡] The goal should be to have a complete, fully functional example of airport weather stations from each major vendor that is supplying aviation weather system to Colombia.

much as 100 m^2 of floor space, or more, plus additional offices and workrooms. This center would require excellent access to high-speed communication links and need to be provided with backup power systems and UPS.

5.4.3 Lightning detection network control room.

The introduction of a national network of lightning detection systems will require a control room for monitoring the system and for generating operational products. This control room should not have to be very large (perhaps 10-15 m^2), but will need to have good access to a variety of communication links and be equipped with backup power and UPS. These central processing and product generation workstations could also be located within an expanded Colombian Aeronautical Meteorology Center forecast center.

5.4.4 Weather radar building and tower.

A weather radar will require a small to moderate-sized building to house the radar electronics and control equipment, and to serve as a local maintenance and control center. In most cases the building would be adjacent to the tower and radome that would house the radar's antenna. The radar will need to be served by a high-speed data line, such as a dedicated T-1 line, for transmitting the beam-by-beam radar imagery to UAEAC and IDEAM meteorological centers. Areas nearby the radar site may need to be controlled to limit future construction (see Section 4.7). The minimum space requirements would be of order 100 m^2 with a backup power system and UPS.

5.4.5 Computing center.

The recommended mesoscale modeling initiative will need to have a moderate-sized computer room and adjacent space for meteorologists, programmers, and supporting services. Since this initiative would most likely be a cooperative effort, the computing center could either be located away from the airport, perhaps at the Universidad Nacional campus in Bogotá, or centralized at the Colombian Aeronautical Meteorology Center (see Working Paper Number 3). The computing center would require at least 100 m^2 with a well air-conditioned computer room of about 20 m^2. The center should be provided with a backup power system with UPS and have excellent communication links in including high-speed broadband internet access.

5.5 Operational expenses and supplies.

To some degree, all operational systems need to be supported with a routine, continuing stock of expendable supplies and materials such as printer paper, ink cartridges, computer disks and storage media. These items are often under budgeted and in short supply. In extreme cases, the limited availability of these basic supplies can seriously limit an organization's operational effectiveness. For an operational upper-air sounding system, the limiting factor is often the availability of radiosondes to launch (see Section 4.5). Purchased in bulk, the Vaisala RS92 radiosonde should cost about US$ 180 per radiosonde. With one launch a day (from a single site) the annual radiosonde supply cost will be about US$ 70,000 or almost US$ 400,000 per year for a full compliment of radiosonde launches (one a day from four sites and two a day at Bogotá).

Plainly and truthfully said, "having good systems that you don't have money to operate doesn't do anybody any good." Maintaining an adequate budget for expendables and other supply items is essential.

6 Implementation and Prioritized Development Plan

This section reviews EarthSat's phased development plan for the Colombian Aeronautical Meteorology System. The plan is divided into a "core" program and a separate list of recommended enhancements. The core program represents a complete, balanced upgrade to the Colombian aviation weather system that is consistent with ICAO standards and recommended practices, and which reflects our review of Colombian users' needs as reviewed in our Working Paper Number 1.

Within the core program, there can be different levels of upgrades. We have presented a recommended program that we feel represents the best balance of technical capability and sustainable budgets. We have, for example, recommended that UAEAC support the development of custom forecasters' workstations (see Section 4.11) since they can provide capabilities designed specifically for the Colombian environment and airspace. There are other, lower-cost, options discussed in the body of the report that would still be a significant improvement over the current state of the Colombian aviation aeronautical system and which could be substituted for our recommended system, if necessary.

Our recommended enhancements to the core program include some major items that are quite expensive. These additional systems are all quite valuable and would significantly improve Colombia's aviation weather program and capabilities. The core program, however, needs to be funded first.

The phased development plan is presented in two spreadsheets that show the recommended implementation plan with annual implementation costs broken down by year over the 2004-2014 period. We have tried to prioritize the planned upgrades and spread their financial impact over the entire program period, while still scheduling some of the most important acquisitions to take place as soon as possible.

The individual components included in the development plan are discussed in detail in Section 4, with additional notes on the implementation schedule included in this section.

It is critical to plan ahead for an adequate maintenance and support budget at the same time as considering an equipment purchase. We have therefore included a maintenance estimate designed to reflect the additional annual support and maintenance costs that will be needed as the plan progresses. In general, the annual support and maintenance costs should be anticipated to total about 10% of the original equipment price (excluding civil works and installation costs). Some systems may be relatively inexpensive to maintain, while others may require a lot of attention. To the extent possible, we have adjusted our estimate of the required maintenance costs to reflect actual maintenance needs and not just rely on a fixed 10% figure.

It needs to be clearly understood that the cost figures show in these worksheets are approximate and basic. There has been no attempt to adjust future year's costs for inflation and the estimates do not include such things as taxes and import duties. The program costs presented are primarily equipment and software and do not include training costs or the costs associated with hiring additional UAEAC staff. Equipment costs are quoted as standard, stock items as normally sold without special customization or enhancements. Actual program costs for budget requests would have to be increased to reflect all of these factors.

It is also important to realize that we are presenting these cost figures in the form of a comprehensive plan, irrespective as to what specific national organizations would be handling the individual procurement or support costs. Thus we have included an explicit line item for radiosonde system upgrades even though they are not current operated or maintained by UAEAC.

6.1 Core program, 2004-2014

The following notes correspond to each horizontal line in the "core program" spreadsheet, Table 6.1. The system upgrades that will be installed at individual airport are also detailed in Appendix B in the form of a tentative installation schedule. :

- UAEAC is currently replacing its aging tower meteorological instrumentation, primarily anemometers and aviation barometers. We expect this to continue and have included an estimate of the annual costs as part of our recommended core program. Since this is part of a regular replacement program, we have only budgeted for limited additional maintenance funding to support these tower systems.

- As a priority, Colombia needs to provide RVR systems and ceilometers for all its current and planned ILS runways. We have recommended a 3-4 year program, detailed in Section 4.2 and Appendix B. To the extent possible, new RVR systems should be acquired in conjunction with airport weather station upgrades to ensure their full integration with the other airport MET systems.

- As one of our major initiatives we have recommended a comprehensive upgrade of Colombia's surface weather observing systems at all of Colombia's controlled airports. This major effort is spread out over the ten-year life of the plan. The gradual introduction of these systems allows time for training plans needed to support anticipated changes to staff duties and responsibilities.

- The current GOES satellite receiving station needs to be replaced. We have recommended the acquisition of a relatively basic LRIT system as soon as possible, with a more substantial acquisition of a high-end GOES/GVAR system timed to coordinate with the acquisition of the forecasters' data integration workstation. **[During the review of this report we learned that AeroCivil has moved ahead and purchased a new GVAR and LRIT system. This item has been retained in Table 6.1, but the system costs are not included in the financial summary figures.]**

- Virtually all of Colombia's upper-air sounding systems need to be upgraded or replaced. We are recommending that this be done as a priority item, over a 2-year period.

- UAEAC needs to acquire its own WAFS workstation. We have budgeted this as a basic, commercial WAFS system equipped with a VSAT data acquisition system (receive only). It is anticipated that the sharing of WAFS data sets among aviation forecasters and local airports will be supported by other systems. **[During the review of this report we learned that AeroCivil has moved ahead and purchased a WAFS system. This item has been retained in Table 6.1, but the system costs are not included in the financial summary figures.]**

- The "Airport MET Networking Upgrades" line item represents new, networked computer workstations for the meteorological data processing at all controlled airports. While these workstations are to be gradually introduced over a 10-year period, the budget also calls for the installed workstations, after installation, to be replaced with new systems on a 3-year cycle.

- The "Forecaster Data Integration Workstation" is a software/hardware combination solution for producing integrated displays off meteorological data sets for use in forecasting. The cost figure is primarily software development with the resultant system designed to be installed on a number of separate workstations. The computer workstations will need to have large-screen, high-resolution displays. The proposed budget includes acquisition funds for system upgrades, hardware or software, every three years.

- The "Software Templates for AIREP & SIGMET" are a separately priced software component of the forecasters' workstation and reflects the same 3-year upgrade cycle.

- Pre-flight briefing materials will be generated and assembled in a separate workstation, which will also act as a server for distributing the products to individual airports. The cost figure reflects a custom development of the appropriate briefing materials for Colombia, with a 3-year upgrade cycle.

- The separate line item for local pre-flight pilot briefing workstations will fund upgraded briefing workstations at every controlled airport.

- The communication upgrade line is an order of magnitude estimate of the costs associated with the UAEAC communication upgrades needed to support the expanded meteorological program.

- The system support for training and calibration includes the purchase of portable, calibration quality meteorological measuring systems as well as two separate purchases of complete, fully-functional airport weather stations for use in training and maintenance (see Section 5.3).

- The line item for airport web cameras will support the acquisition of web cameras for every controlled airport, to be installed in conjunction with the airport weather system upgrades.

6.2 Recommended program enhancements

The following notes correspond to each horizontal line in the "recommended program enhancements" spreadsheet, Table 6.2: In each of these specialized program enhancements we have included explicit line items for consultant services and for maintenance and support. For major systems of the sort included in this list, EarthSat recommends that expert consultants be hired to assist with the preparation of the system specifications and installation to ensure that the systems are well suited to Colombian needs.

- *Lightning detection network.* While EarthSat feels that a Colombian lightning detection network would be a valuable addition to the national aeronautical meteorology program, its cost puts it into a special category for evaluation. This system, however, would be of unique value in identifying the location, strength, and movement of Colombia's major convective storms, helping forecasters identify which storms are major hazards to aviation.

- *Doppler weather radar.* Specialized weather radars are expensive, but are widely used to monitor convective storms. The limited coverage of a single weather radar, however, makes it a lower priority than the lightning detection network. We have suggested that Colombia consider acquiring a weather radar mid-way through the proposed ten-year phased development plan so it can augment the other system improvements instead of replacing them.

- *Windshear Detection and Monitoring Systems.* Colombia has identified a number of airports that suffer from frequent occurrences of turbulence and windshear, particularly Pasto. In this option we have budgeted for extended wind monitoring systems for three airports, augmented by a portable tethersonde system. The first installation is anticipated to be at Pasto, with subsequent installation at Bucaramanga, and Providencia. The installations are separated by several years to allow each installation to be evaluated before adding the system another airport.

- *Mesoscale modeling center.* The modeling center represents a commitment to making a fundamental improvement in aviation forecasting for Colombia. The funding identified in the spreadsheet are primarily computers, analysis workstations, and infrastructure for ingesting weather information for use in the initialization of the model. Two separate options are presented for the modeling center. The first option is more gradual and for the most part is based on

Colombian leadership and expertise. The second option depends more heavily on international consultants and is designed to accelerate the modeling effort.

6.3 Phase II, 2015 and beyond

While the proposed phased development plan will represent a major enhancement to the Colombian aeronautical meteorological system, there will still be a need for periodic system upgrades and enhancements after 2014, reflecting new technological developments, updated international standards, and changing user needs.

Even now we can see a number of potential system enhancements that cannot be completed within the current ten-year plan. Possible follow-on initiatives include:

- Install airport weather stations at additional airports, including currently uncontrolled airports in the east and southeast. Additional stations in these areas would provide a better geographical balance to the observations and fill in data gaps in these areas. In particular, the uncontrolled airports that are designated for receiving lightning detection sensor would be good candidates for automatic weather stations since they can make use of the communication links that will have to be provided for the lightning data.

- Upgrade the AWOS-3 weather station installed under this ten-year plan to include present weather sensors and automatic raingages.

- Expand the national lightning detection network into a regional network through collaborative efforts with surrounding countries.

- Add additional RVR and ceilometer systems for CAT-I airports that are currently only being provided with a single RVR and ceilometer.

- Begin plans to update the GOES satellite receiving station for the GOES-R generation of spacecraft. These future systems will require completely new receiving stations to support major enhancements in satellite capabilities and higher speed data transmission.

- Install additional Doppler radars.

- Acquire AMDAR data to provide additional sounding profiles and better model initialization.

TABLE 6.1 RECOMMENDED CORE PROGRAM FOR THE PHASED DEVELOPMENT PLAN

Modernization Options	Calendar Year Expenditures (US $ x 1000)										
	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Basic Control Tower MET Systems		30	30	30	30	30	30	30	30	30	30
RVR and Ceilometers for ILS Runways		250	300		120	60					
Comprehensive AWOS Replacement Program		400	780	420	380	320	350	400	500	400	600
GOES Receiving Systems (2004 purchase)		~~40~~	~~100~~								
Radiosonde and Upper Air Soundings		150	40								
WAFS Workstation (acquired in 2004)		~~75~~									
Airport MET Networking Upgrades			25	25	25	50	50	50	75	75	75
Forecaster Data Integration Workstation			300			50			50		
Software Templates for AIREP and SIGMET			50	150		20			20		
Pre-flight (Pilot) Briefing System & Software				250		25			25		
Local Pre-flight Weather Briefing, User Workstations					30	30	30	30	30	30	30
Communication Upgrades (MET data distribution)		50	50	50	50	50	50	50	50	50	50
Weather Systems for Training & Calibration		20	20	100	20	100	10				
Airport Web Cameras		20	20	20	20	20	20	20	20	20	20
Equipment Total	0	920	1,615	1,045	675	755	540	580	800	605	805
Maintenance Cost	0	17	95	200	300	350	400	450	500	550	600
TOTAL	0	937	1,710	1,245	975	1,105	940	1,030	1,300	1,155	1,405

TABLE 6.2 RECOMMENDED OPTIONS FOR THE PHASED DEVELOPMENT PLAN

Modernization Options	Calendar Year Expenditures (US $ x 1000)										
		2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Lightning Detection Network		100	1,000	1,200	1,200	250					
Maintenance & Support Lightning Network			10	75	85	95	100	100	100	100	100
Consultant Services (site selection)		50	10								
Doppler Weather Radar							425	1,800	1,000	200	50
Maintenance & Support for Doppler Radar								25	200	300	300
Consultant Services (radar systems and installation)							75	50	50	75	25
Windshear Detection & Monitoring Systems			250	100			250		250		
Maintenance & Support for Windshear Systems				15	25	35	35	50	60	70	80
Consultant Services (terrain induced windshear)		50	50			50	50	50	50		
Mesoscale Modeling Center		50	200	500	200		300			300	
Maintenance & Support Costs for Computer Center			10	30	80	100	100	100	100	100	100
Consultant Services (model setup and support)		75	75	75	75						
Mesoscale Modeling Center — FAST OPTION		50	600	300	100		300			300	
Maintenance & Support Costs for Computer Center			10	70	90	100	100	100	100	100	100
Consultant Services (model applications and operation)		200	400	400	400	300	300	300	300	300	300

7 Summary

The overall goal of this phased development plan for the modernization of the Colombian aeronautical meteorology system is to provide an enhanced level of service that reflects international commitments and users' needs.

The principal objectives of aeronautical meteorological services are to support air traffic management, to provide services to pilots in-flight and preflight, and to support other users such as dispatchers and airport operators.

Weather adversely affects the efficiency of aviation operations by hindering the ability to meet the demand for capacity at airports and in the en-route airspace. In the United States, the primary cause of delays of 15 minutes or higher is consistently weather, which accounts for 65 – 70% of these delays. With respect to safety, data from the U.S. National Transportation Safety Board indicate that weather is a factor in nearly 23% of all accidents. With an anticipated ten year growth of 28 to 49% in Colombian air traffic (Working Paper Number 1, Section 1.3) it is clear that any inefficiencies, delays, and weather safety concerns that exist within the system will increase in proportion with the increase in air traffic volume

Our plan proposes an upgrade to around the clock services through centralization and automation. The system will be built on modernized observational systems, enhanced communications, and improved products.

And in the end, we anticipate a system that gives more attention to users' needs for safety and efficiency and less on trying to meet minimum requirements.

7.1 Key decisions

While the overall program plan has many aspects, there are a couple of issues that have to be decided at the very start of the multi-year program.

Perhaps the single most critical decision is whether to build the program around a company or consortium of companies that can act as the primary system integrator, coordinating the program and being responsible for identifying subcontractors and providing critical observing system upgrades. In particular, the forecasters' workstation, data access systems (GOES satellite, WAFS, and access to full resolution model data sets), AIREP and SIGMET templates, and pre-flight pilot briefing systems might be very efficient if done as a single project.

The second most critical decision is whether to try to use existing commercial solutions with limited customization of forecasters' workstations and pre-flight pilot briefings, or to develop a more sophisticated system with advanced products and greater customization. This may be an area where an open "request for information" could solicit a range of possible solutions from potential vendors that could be discussed in an "Aviation Meteorology Users' Conference" with airlines, civil aviation authorities, and meteorologists.

Another early decision that might be discussed in a users' conference format is whether or not it is realistic in terms of funding and national capability to try to move ahead with some of the recommended options for the ten-year plan, such as the lightning detection network, Doppler radar, or mesoscale modeling center.

7.2 Operational requirements, meteorological products, and automation

The phased development plan presented in this document is designed to be consistent with all the relevant WMO and ICAO standards, specifically including the standards and recommended practices described in Annex 3 to the Convention on International Civil Aviation (ICAO, 2001).[§§] Other defining documents include the CAR/SAM Basic Air Navigation Plan (ANP), CAR/SAM Facilities and Services Implementation Document (FASID), and the CAR/RAM Regional Plan for the Implementation of the CNS/ATM Systems. These documents were reviewed and summarized in EarthSat's Working Report Number 1 (Table 3.1, page 18), along with a summary of the airport-by-airport responsibilities for meteorological services specified by the Colombian Aeronautical Information Publication (AIP) within the context of a summary of the current state of the Aeronautical Meteorology System (see Table 4.1, page 42).

Perhaps the most important ICAO document with specific reference to the Colombian Aeronautical Meteorology for guiding our recommendations is the Report of the Sixth Meeting of the CAR/SAM Aeronautical Meteorology Subgroup (ICAO, 2003) that specifically reviewed the current state of the CAR/SAM member states' meteorological programs and highlights deficiencies.

While international standards and requirements, such as those given by ICAO, are essential for safe and efficient international air routes, they do not necessarily provide for all the meteorological information that is needed for a country to provide a safe and efficient aviation system. Perhaps the best way to evaluate the meteorological needs is to talk with the users of the aviation system. Section 4.7 in EarthSat's Working Paper Number 1 summarized our discussion with the users of the aviation system, including airlines, dispatchers, and pilots. To put the Colombian end-user viewpoint into a broader context, we also reviewed a number of international documents that review the current and developing aviation needs for weather information and point the direction toward which aviation weather systems should be headed (see Section 3.4 in Working Paper Number 1).

[§§] While this report was being reviewed by UAEAC, ICAO issued a new edition of Annex 3 (15th Edition). An examination of the Annex 3 changes confirms that all aspects of the EarthSat phased development are fully compliant with the new edition of Annex 3.

At present, METARs are the heart of the Colombian aviation meteorological system. METARs are collected at almost all of Colombia's controlled airports, even exceeding the AIP meteorology plan requirements. Terminal area forecasts (TAFs) are only issued for 7 of the 8 international airports, with little guidance being provided for domestic flights other than looking at the most recent METAR and hoping that the weather doesn't change.

The Colombian radiosonde system is well designed and makes important contributions to the WMO's World Weather Watch, but Colombia has not been able to maintain a full program of soundings and does not seem to make full use of the soundings that are launched.

Colombia's surface observing system operates at a rather basic level, without the automated runway visual range (RVR) and ceilometer observations that are required under ICAO standards. A broader enhancement of the surface observing system to include automatic systems to monitor visibility and cloud base height as part of fully automatic reporting system that would operate 24 hours a day at all airports would provide better weather information for flight operations and planning, while at the same time giving Colombia's aviation forecasters more information to work from.

Other than the standard WAFS "flight folder" products, pre-flight briefing materials are of limited value and seldom, if ever, include timely SIGMETs or special AIREPs.

From our perspective, the critical issues is one of not just trying to meet minimum international standards, but rather to work with the whole Colombian aviation community do identify those areas where additional (or better) weather information will have a definite impact on safety and efficiency. Major areas of importance, such as improving the quality of forecasts, can't be addressed individually, but will rather be the end result of a broader effort to improve observational systems, increase the number of trained meteorologists, and improve efficiency.

It is important to emphasize that improvements to aviation meteorological services will not only be of use to airlines, pilots, and dispatchers, but will also provide critical operational information for UAEAC's ATC and AIS personnel.

EarthSat's overall approach is to try to extend the "international standards" as defined by ICAO to cover domestic flights as well. This will mean making more observations and providing more services throughout the country.

In order to accomplish these goals, there will need to be a significant transition to increased automation in the meteorological system, from observations to data distribution, analysis, product generation, and dissemination to end users. Automated systems would provide around-the-clock observations with fewer trained observers, while using the existing staff to put a new emphasis on maintenance, forecasting, and pre-flight briefing. With the possible introduction of automated, self-service weather briefing stations, full weather services can be extended to every airport.

This transition would be a big change for Colombia, but is fully consistent with the future enhancements to aviation services expected from the meteorological aspects of the upcoming CNS/ATM improvements such as more data, fully networked communication links, improved data access, and better visualization and displays for all weather products.

7.3 Operational impact.

The proposed phased development plan for the modernization of the Colombia aeronautical meteorology system should have a major impact on aviation weather services in Colombia. It will also impact UAEAC, its organization, and how it works.

In particular, there is likely to be a significant impact on airport communication links with significantly increased traffic in meteorological data to all controlled airports and a need for expanded network connections and new communication links. Communication capacities may need to be increased and electronic data networks expanded to reach more airports. The AFTN will almost certainly have to be modernized and every controlled airport will need to have an operational ATIS capability for broadcast of airport weather information.

The recommended expansion of meteorological systems will mandate a new emphasis on system maintenance to keep these new systems operational and accurate. The cost of maintenance, with an annual budget requirement in the vicinity of 10% of the original equipment price, will be a major factor that needs to be considered before equipment is purchased. If there isn't money to maintain a new system, it may not be a good idea to buy it.

In some cases there will also be a need to find a way to accumulate unused maintenance funds into a reserve fund that will be able to cover major system failures or replacements that would otherwise need to wait for additional budget allocations.

With increased centralization of AeroCivil meteorological responsibilities there is likely to be a reduction in full-time MET staff at most Colombian airports. While the new automatic weather stations will be able to generate METARs and other weather reports around the clock, even when the airport is closed, there will still be a need for occasional manual enhancements to the hourly METAR reports during operational hours. The needed enhancements will not be time consuming and should be able to be accomplished without significantly impacting the other duties of airport staff.

All controlled airports are expected to receive self-service workstations for pre-flight weather briefings and these workstations will normally be installed in existing AIS spaces, with an accompanying obligation for AIS staff to ensure that they are well maintained and available to users. New users of these self-briefing weather stations may need assistance until they become familiar with them.

The recommended AWOS-3 weather station configuration includes ceilometers at every airport. These systems require AC line power. Since most existing Colombian airport weather systems are powered by solar panels, this requirement will necessitate a review of power distribution systems at most Colombian airports. In some cases it may be possible to separate the ceilometers from the other weather sensors to facilitate the power installation. In all cases, however, the new meteorological systems should be powered as essential airport systems with whatever backup power capabilities that are available at the airport.

7.4 Program reviews.

Any long term program plan needs to be reviewed and updated as the plan progresses. EarthSat recommends that UAEAC conduct formal, program reviews every two years, including public sessions for pilots, airlines representatives, and other interested parties. These reviews would summarize progress, discuss future system upgrades, and review user needs.

In support of these periodic reviews, EarthSat also recommends that Colombia bring in independent consultants to participate in these program reviews and prepare a formal written report evaluating the enhanced meteorological systems and future plans.

7.5 Long-term infrastructure upgrades and initiatives.

While EarthSat's recommendations are focused on specific system upgrades that will help improve the Colombian aeronautical meteorological system, there are also a number of more general infrastructure upgrades and initiatives that are needed to compliment and support these MET system improvements. These long-term, general upgrades and initiatives include:

- Greater availability of well qualified meteorological personnel through improved technical education initiatives and enhanced university degree programs.
- Improved regional cooperation among meteorological agencies in nearby countries.
- High-speed, broadband digital communication links at all controlled airports.
- Upgrade and modernize the Colombian AFTN system for network access.
- Enhanced airport power systems, including UPS and backup generators, at all controlled airports.

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APPENDIX A

Aeronautical Meteorological Infrastructure: Summary Tables Reviewing Requirements, Recommendations, Options and Products

Strictly speaking, ICAO requirements only apply to International Airports. Domestic airports, however, have the same safety needs and should be provided with the same level of meteorological services. To the extent possible, EarthSat recommends that UAEAC apply ICAO standards to all controlled airports.

As discussed in Section 4.1, EarthSat recommends that Colombia transition to a standard automatic weather station configuration to be installed at all controlled airports.

Airport specific requirements are needed in support of International Airports and airports with ILS runways. Other airports have difficulties with terrain-induced windshear and turbulence, for which we are recommending a limited number of airport specific instrumentation upgrades. In general, however, weather requirements and expectations should be uniform from airport to airport.

Table A-1: Recommended and Required Meteorological Products at Colombian Controlled Airports.

Table summarizes the ICAO and WMO requirements for meteorological products for controlled airports, based on the materials presented in Working Paper Number 1.

The first four columns in this table describe each airport in terms of their respective UAEAC categories, ICAO designation as an international airport, and the airport's support for instrument landing capabilities (ILS). The remained 12 columns highlight the corresponding recommended and required meteorological products.

ILS and ICAO-designated International Airports are expected to have RVR and ceilometers located at the runway threshold or middle marker in support of instrument landings. RVR and ceilometers are required for CAT-II landing systems and are recommended for CAT-I landing systems. Regional standards stress the need for RVR systems for ILS runways (ICAO, 2003). In principle, each ILS system should be supported by RVR and cloud base height measurements, meaning that runways supported for landings from both directions should provide separate RVR and ceilometers at each end or the runway. EarthSat recommends that CAT-II runways be equipped with RVR and ceilometers at each end of the runway. For CAT-I runways, EarthSat recommends that airports have at least one RVR and ceilometer to support landings on an instrumented runway. The RVR and ceilometer observations should be integrated with the standard airport weather observing systems for inclusion into METARs and not limited to local use in support of landings and takeoffs

Weather observations are critical for all airport operations and domestic flights should be supported at the same standards for safety and efficiency as International Airports. EarthSat recommends that Colombia apply ICAO International Standards for TAFs, weather briefing materials, and aerodrome climatologies to all controlled airports.

Table A-1: Recommended and Required Meteorological Products at Colombian Controlled Airports.

AIRPORT	[illegible] CATEGORY	ICAO	ILS	[illegible]	METAR & SPECI	MANUAL AUGMENT	Aeronautical Climatology	WMO SYNOP	WMO RBSN	WMO CLIMAT	WMO RBCN	TAF	WEATHER BRIEFING	WMO TEMP [illegible]	WMO [illegible]
BOGOTÁ	A-1	INTL	Cat I & II	REQUIRED	REQUIRED	REQUIRED	REQUIRED	X	X	X	X	REQUIRED	REQUIRED	2X, RBSN	RBCN
CALI	A-1	INTL	Cat I	RECOMMENDED	REQUIRED	REQUIRED	REQUIRED	X	X	X	X	REQUIRED	REQUIRED		
RIONEGRO	A-1	INTL	Cat I → II	REQUIRED	REQUIRED	REQUIRED	REQUIRED	X	X	X	X	REQUIRED	REQUIRED		
CARTAGENA	A-1	INTL	→ Cat I	RECOMMENDED	REQUIRED	REQUIRED	REQUIRED	X	X	X	X	REQUIRED	REQUIRED		
BUCARAMANGA	A-1		→ Cat I	RECOMMENDED	RECOMMENDED	RECOMMENDED	RECOMMENDED	X	X	X	X	RECOMMENDED	RECOMMENDED		
BARRANQUILLA	A-1	INTL	Cat I	RECOMMENDED	REQUIRED	REQUIRED	REQUIRED	X	X	X	X	REQUIRED	REQUIRED		
PEREIRA	A-2			—	RECOMMENDED	RECOMMENDED	RECOMMENDED	X	X	X	X	RECOMMENDED	RECOMMENDED		
CUCUTA	A-1	INTL	Cat I	RECOMMENDED	REQUIRED	REQUIRED	REQUIRED	X		X		REQUIRED	REQUIRED		
SAN ANDRES	A-1	INTL	→ Cat I	RECOMMENDED	REQUIRED	REQUIRED	REQUIRED	X	X	X	X	REQUIRED	REQUIRED	RBSN	RBCN
LETICIA	A-1	INTL	Cat I	RECOMMENDED	REQUIRED	REQUIRED	REQUIRED	X	X	X	X	REQUIRED	REQUIRED	RBSN	RBCN
VILLAVICENCIO	B-1			—	RECOMMENDED	RECOMMENDED	RECOMMENDED	X	X	X	X	RECOMMENDED	RECOMMENDED		
EL YOPAL	B-2			—	RECOMMENDED	RECOMMENDED	RECOMMENDED					RECOMMENDED	RECOMMENDED		
NEIVA	B-3			—	RECOMMENDED	RECOMMENDED	RECOMMENDED	X	X	X	X	RECOMMENDED	RECOMMENDED		
SANTA MARTA	B-2			—	RECOMMENDED	RECOMMENDED	RECOMMENDED	X	X	X	X	RECOMMENDED	RECOMMENDED		
ARMENIA	B-3			—	RECOMMENDED	RECOMMENDED	RECOMMENDED	X		—	X	RECOMMENDED	RECOMMENDED		
MANIZALES	B-2			—	RECOMMENDED	RECOMMENDED	RECOMMENDED	X		—		RECOMMENDED	RECOMMENDED		
IBAGUE	B-3			—	RECOMMENDED	RECOMMENDED	RECOMMENDED	X	X	X	X	RECOMMENDED	RECOMMENDED		
PASTO	B-3		→ Cat I	RECOMMENDED	RECOMMENDED	RECOMMENDED	RECOMMENDED		X		X	RECOMMENDED	RECOMMENDED		
MONTERIA	B-2			—	RECOMMENDED	RECOMMENDED	RECOMMENDED	X	X	—		RECOMMENDED	RECOMMENDED		
CARTAGO	B-4			—	RECOMMENDED	RECOMMENDED	RECOMMENDED					RECOMMENDED	RECOMMENDED		
IPIALES	B-4			—	RECOMMENDED	RECOMMENDED	RECOMMENDED	X		X	X	RECOMMENDED	RECOMMENDED		
QUIBDO	B-2			—	RECOMMENDED	RECOMMENDED	RECOMMENDED	X	X	X	X	RECOMMENDED	RECOMMENDED		
POPAYAN	B-3			—	RECOMMENDED	RECOMMENDED	RECOMMENDED		X			RECOMMENDED	RECOMMENDED		
MEDELLIN	B-2			—	RECOMMENDED	RECOMMENDED	RECOMMENDED	X		—		RECOMMENDED	RECOMMENDED		
GUAYMARAL	B-2			—	RECOMMENDED	RECOMMENDED	RECOMMENDED					RECOMMENDED	RECOMMENDED		
SAN JOSE DEL GUAVIARE	C-3		Cat I	RECOMMENDED	RECOMMENDED	RECOMMENDED	RECOMMENDED	X	X	—		RECOMMENDED	RECOMMENDED		
BAHIA SOLANO	C-4			—	RECOMMENDED	RECOMMENDED	RECOMMENDED					RECOMMENDED	RECOMMENDED		
GIRARDOT	C-3			—	RECOMMENDED	RECOMMENDED	RECOMMENDED	X		X		RECOMMENDED	RECOMMENDED		
MARIQUITA	C-4			—	RECOMMENDED	RECOMMENDED	RECOMMENDED					RECOMMENDED	RECOMMENDED		
FLORENCIA	C-4			—	RECOMMENDED	RECOMMENDED	RECOMMENDED	X		—		RECOMMENDED	RECOMMENDED		
CAREPA	C-2			—	RECOMMENDED	RECOMMENDED	RECOMMENDED	X	X	X	X	RECOMMENDED	RECOMMENDED		
PUERTO ASIS	C-4			—	RECOMMENDED	RECOMMENDED	RECOMMENDED	X	X	—		RECOMMENDED	RECOMMENDED		
VALLEDUPAR	C-3			—	RECOMMENDED	RECOMMENDED	RECOMMENDED	X	X	—		RECOMMENDED	RECOMMENDED		
MITU	C-4			—	RECOMMENDED	RECOMMENDED	RECOMMENDED		X			RECOMMENDED	RECOMMENDED		
PROVIDENCIA	C-3			—	RECOMMENDED	RECOMMENDED	RECOMMENDED		X		X	RECOMMENDED	RECOMMENDED		
RIOHACHA	C-4			—	RECOMMENDED	RECOMMENDED	RECOMMENDED	X	X	—	X	RECOMMENDED	RECOMMENDED	RBSN	RBCN
PUERTO CARREÑO	D-4			—	RECOMMENDED	RECOMMENDED	RECOMMENDED	X	X	X	X	RECOMMENDED	RECOMMENDED		
ARAUCA	D-2			—	RECOMMENDED	RECOMMENDED	RECOMMENDED	X	X	X		RECOMMENDED	RECOMMENDED		
BARRANCABERMEJA	D-2			—	RECOMMENDED	RECOMMENDED	RECOMMENDED	X		X	X	RECOMMENDED	RECOMMENDED		
BUENAVENTURA	D-4			—	RECOMMENDED	RECOMMENDED	RECOMMENDED	X	X	X		RECOMMENDED	RECOMMENDED		
COROZAL	D-4			—	RECOMMENDED	RECOMMENDED	RECOMMENDED	X		—		RECOMMENDED	RECOMMENDED		
GUAPI	D-4			—	RECOMMENDED	RECOMMENDED	RECOMMENDED					RECOMMENDED	RECOMMENDED		
OCAÑA	D-4			—	RECOMMENDED	RECOMMENDED	RECOMMENDED	X		—		RECOMMENDED	RECOMMENDED		
SAN VICENTE DEL CAGUAN	D-4			—	RECOMMENDED	RECOMMENDED	RECOMMENDED	X		—		RECOMMENDED	RECOMMENDED		
SARAVENA	D-3			—	RECOMMENDED	RECOMMENDED	RECOMMENDED					RECOMMENDED	RECOMMENDED		
TAME	D-4			—	RECOMMENDED	RECOMMENDED	RECOMMENDED					RECOMMENDED	RECOMMENDED		
TUMACO	D-4			—	RECOMMENDED	RECOMMENDED	RECOMMENDED	X		—		RECOMMENDED	RECOMMENDED		
PUERTO INIRIDA	?			—	RECOMMENDED	RECOMMENDED	RECOMMENDED					RECOMMENDED	RECOMMENDED		
LAS GAVIOTAS	—							X	X	X	X			RBSN	RBCN

Las Gaviotas is an IDEAM upper-air sounding site, but not located at a controlled airport.

Cells highlighted in blue indicate sites that are part of the GSN or GUAN

Table A-2: Recommended and Required Meteorological Products from the Bototá Meteorological Watch Office.

ORGANIZATION	MET WATCH	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
BOGOTÁ, MWO	REQUIRED	REQUIRED	REQUIRED	REQUIRED	RECOMMENDED	REQUIRED	REQUIRED	REQUIRED	RECOMMENDED	RECOMMENDED

In Table 3-1, meteorological products are shown as being **REQUIRED** for ICAO designated International Airports, and are listed as **RECOMMENDED** for all other controlled airports.

METARs, SPECI, TAFs, and Weather Briefings are shown as being required or recommended for all controlled airports. ICAO standards for Aerodrome Climatologies mandate a 5-year climatological record, but strictly speaking do not require that the climatology be continually updated. The intent of the standards and recommended practices, however, are clear and EarthSat recommends that airdrome climatologies should be maintained monthly and routinely updated.

To the extent possible, meteorological observations and hourly METARs should be provided around the clock. In most cases, this requires automatic observing stations that can update observations and generate METARs even during hours that the airport is closed. EarthSat recommends that Colombia upgrade to a full national system of automatic weather stations. During hours that the airport is open and trained meteorologists are available, ICAO recommends that automatic METARs be augmented by manual observations of cloud type, cloud properties (beyond those properties that can be determined by a ceilometer), and present weather according to ICAO codes.

At present, ICAO does not believe that a fully automatic observing system can be fully compliant with Annex 3 standards. Countries, such as the United States, that do rely on fully automatic observations generally file formal "exceptions" to the ICAO standards and describe the capabilities and limitations to their own national observing systems. On the other hand, it is relatively easy to add manual enhancements to a METARs when conditions merit it, so long as the routine aspects of the task are fully automated.

EarthSat recommends that Colombia provide manual enhancements to automatically produced METAR reports to the extend permitted by staffing and personnel assignments. At International Airports, UAEAC may wish to maintain at least one MET trained staff member on duty during operational hours to provide weather briefing services and augment the automatic METARs to provide fully compliant METARs.

Although not a direct UAEAC responsibility, Colombia's WMO commitments frequently involve observations from airports. As discussed in Working Paper Number 1, the WMO expectations for SYNOP reports and corresponding monthly CLIMAT-C reports are often inconsistent and differ somewhat from those of the Regional Basic Synoptic Network (RBSN) and the Regional Base Climatological Network (RBCN) stations. As part of any plans for upgrading aviation weather services and reports, it is essential that UAEAC and IDEAM coordinate their activities to ensure that all national commitments to the international meteorological community can be met, and update WMO and ICAO documents to reflect realistic national meteorological capabilities and commitments.

Upper-air soundings (WMO TEMP report) are also an WMO commitment, with five radiosonde sites being identified in Colombia with a corresponding requirement for monthly climatological sounding summaries (WMO CLIMAT–T report). Sounding summaries from Bototá are widely used internationally as part of the GUAN.

Performance standards for meteorological observation systems and forecast products are discussed in ICAO's Annex 3, Attachment B, titled "Operationally Desirable and Currently Attainable Accuracy of Measurement or Observation," Attachment C, titled

"Selected Criteria Applicable to Aerodrome Reports," and Attachment E, titled "Operationally Desirable Accuracy of Forecasts." Additional standards for observing system performance are provided in FAA Advisory Circular Number 150/5220-16C.

Table A-2: Recommended and Required Meteorological Products from the Bogotá Meteorological Watch Office.

Table A-2 summarizes the national airspace products required for the Bogotá MWO. The most basic requirement is to monitor the meteorological conditions that can influence the safety and efficiency of civil aviation and to provide meteorological support and guidance to Colombian ATC Area Control Centers (ACC). Based on ICAO documents, as reviewed in Working Paper Number 1, the basic requirements include issuing SIGMETs, AIREPs, and TAFs for regionally designated airports. The TAF responsibility is originally assigned to the individual airport meteorological offices, but has been delegated to the Bogotá MWO. AIRMETs are not required, by regional agreement. Area forecasts (including plain language forecasts) and route forecasts (ROFOR) are not required, but are valuable and should be provided. In Colombia most flights for which a route forecast would be most valuable would be the long flights to and from Leticia and San Andres.

EarthSat recommends that Colombia provide Area Forecasts, Route Forecasts, and AIRMETs as required to serve domestic and international air traffic.

The Bogotá MWO is also the designated national point of contact with the Volcanic Ash Advisory Center (VAAC) and the Tropical Cyclone Advisory Center (TCAC).

Performance standards for forecast accuracy are discussed in ICAO's Annex 3, Attachment E, titled "Operationally Desirable Accuracy of Forecasts."

Table A-3: EarthSat Recommended Instrumentation and Observational Facilities for Colombian Airports.

Table A-3 summarizes the EarthSat recommended instrumentation and observational facility upgrades for Colombian airports. The left-hand column lists the 47 Colombian controlled airports, plus one additional airport (Puerto Inirida) which is expected to be upgraded to controlled status during the ten-year term of this plan. The airports listed at the bottom of this column (below Puerto Inirida) are uncontrolled airports that included in the presentation because they are being recommended as installation sites for lightning network sensors. Radiosonde upgrades and enhancements are not summarized in this table.

EarthSat recommends the installation of upgraded automatic weather stations at all controlled airports. The standard, base, recommended specification (termed AWOS-3 within the context of this report) for these weather stations includes dual pressure sensors, temperature, relative humidity (or dew point), wind speed and direction, visibility and cloud ceiling. The inclusion of a ceilometer in this basic configuration will be a challenge since ceilometers require line power and can not be run from solar panels and batteries. EarthSat, however, considers routine observations of ceiling and visibility to be essential for safe and efficient airport operations. For airports without ILS runways,

Table A-3: EarthSat Recommended Instrumentation and Observational Facilities for Colombian Airports

Airports Identified by Category, Operational Status, and Communication Links						Instrumentation and Observational Facilities					
AIRPORT	UAEAC CATEGORY	ICAO	ILS	HOURS	COM	WEATHER OBS	EXTRA SENSORS	WIND SHEAR SYSTEM	RVR & Ceilometer	LIGHTNING SENSOR	INTEG
BOGOTÁ	A-1	INTL	Cat I & II	24	HUB	AWOS-3	**Optional-1**		**2X & 2X**		X
CALI	A-1	INTL	Cat I	24	VSAT+MW	AWOS-3	Optional		X		X
RIONEGRO	A-1	INTL	Cat I → II	24	VSAT+MW	AWOS-3	Optional		2X		X
CARTAGENA	A-1	INTL	→ Cat I	24	VSAT+MW	AWOS-3	Optional		X		X
BUCARAMANGA	A-1		→ Cat I		MW	AWOS-3	Optional	X	X		X
BARRANQUILLA	A-1	INTL	Cat I	24	VSAT+MW	AWOS-3	Optional		X		X
PEREIRA	A-2				VSAT+MW	AWOS-3	Optional				
CUCUTA	A-1	INTL	Cat I		VSAT+MW	AWOS-3	Optional		X		X
SAN ANDRES	A-1	INTL	→ Cat I		VSAT	AWOS-3	**Optional-2**		X	Future	X
LETICIA	A-1	INTL	Cat I		VSAT	AWOS-3	Optional		X	X	X
VILLAVICENCIO, NOTE 4	B-1				VSAT+MW	AWOS-3	Optional			X	
EL YOPAL	B-2				VSAT	AWOS-3	Optional			X	
NEIVA	B-3				VSAT	AWOS-3	Optional				
SANTA MARTA	B-2				MW	AWOS-3	Optional				
ARMENIA	B-3				MW	AWOS-3	Optional			X	
MANIZALES	B-2				VSAT	AWOS-3	Optional				
IBAGUE	B-3				MW	AWOS-3	Optional				
PASTO	B-3		→ Cat I		VSAT	AWOS-3	Optional	X	X		X
MONTERIA	B-2				VSAT+MW	AWOS-3	Optional			X	
CARTAGO	B-4				MW	AWOS-3	Optional				
IPIALES	B-4				VSAT	AWOS-3	**Optional-1**				
QUIBDO	B-2				VSAT	AWOS-3	Optional			X	
POPAYAN	B-3				MW	AWOS-3	Optional			X	
MEDELLIN	B-2				MW	AWOS-3	**Optional-3**				X
GUAYMARAL	B-2				MW	AWOS-3	Optional				
SAN JOSE DEL GUAVIARE	C-3		Cat I		VSAT	AWOS-3	Optional		X	X	X
BAHIA SOLANO	C-4				—	AWOS-3	Optional			Optional	
GIRARDOT	C-3				—	AWOS-3	Optional				
MARIQUITA	C-4				—	AWOS-3	Optional				
FLORENCIA	C-4				VSAT	AWOS-3	Optional				
CAREPA	C-2				VSAT	AWOS-3	Optional			X	
PUERTO ASIS	C-4				VSAT	AWOS-3	Optional			X	
VALLEDUPAR	C-3				VSAT+MW	AWOS-3	Optional			X	
MITU	C-4				VSAT	AWOS-3	Optional			X	
PROVIDENCIA	C-3				VSAT	AWOS-3	**Optional-2**	X		Future	X
RIOHACHA	C-4				VSAT	AWOS-3	Optional			X	
PUERTO CARREÑO, NOTE 5	D-4				—	AWOS-3	Optional			X	
ARAUCA	D-2				VSAT+MW	AWOS-3	Optional			X	
BARRANCABERMEJA	D-2				MW	AWOS-3	Optional				
BUENAVENTURA	D-4				—	AWOS-3	Optional				
COROZAL	D-4				—	AWOS-3	Optional				
GUAPI	D-4				—	AWOS-3	Optional				
OCAÑA	D-4				MW	AWOS-3	Optional				
SAN VICENTE DEL CAGUAN	D-4				VSAT	AWOS-3	Optional			X	
SARAVENA	D-3				MW	AWOS-3	Optional				
TAME	D-4				MW	AWOS-3	Optional				
TUMACO	D-4				VSAT	AWOS-3	Optional			X	
PUERTO INIRIDA	?				?	AWOS-3	Optional			X	
EL BANCO	—				?	Optional	Optional			X	
ARARACUARA	—				?	Optional	Optional			X	
LAS GAVIOTAS, NOTE 6	—				?	—	—			X	
BARRANCOMINA	—				?	Optional	Optional			X	
LA PEDIERA	—				?	Optional	Optional			X	
PUERTO LEGUIZAMO	—				?	Optional	Optional			X	
ARICA	—				?	Optional	Optional			X	
TARAPACÁ	—				?	—	—			Optional	
PUERTO BOLIVAR	—				?	—	—			Optional	
MIRAFLORES	—				?	—	—			Optional	

Note #1: Since the Bogota and Ipiales airports are at very high eleveation, we recommend that UAEAC consider installing heaters for deicing meteorological sensors at these two airports.

Note #2: Since San Andres and Provicencia are to far away from mainland Colombia to be part of the recommended National Lightning Detection Network, we suggest that Colombia consider installing a single-point, thunderstorm detection sensor as an enhancement to each of the AWOS-3 systems installed at San Andres and Providencia.

Note #3: Considering its heavy traffic, central down-town location, and frequent closures due to low ceilings and poor visibility, we recommend that Colombia consider enhancing the basic AWOS-3 system recommended for Medellin (Enrique Olaya Herrera Airport) with ceiling and visibility sensors at each end of the runway.

Note #4: The recommended ligntning sensor to be installed in Villavicencio might be better located at the Aplay Air Base, just to the east of Villavicencio.

Note #5: The recommended ligntning sensor to be installed in Puerto Carreña might be better located at the nearby Marandúa Air Base.

Note #6: The ligntning sensor recommended for installation in Las Gaviotas might also be able to be installed at the nearby Carimagua ATC Radar site. It is not clear whether the non-controlled airport at Gaviotas is still operational or if the IDEAM radiosonde site at Los Gaviotas is still functional, so this site may be problematic.

ceilometers do not necessarily have to be co-located with the rest of the MET observing systems and may be placed in a suitable location that can be provided with AC line power. It is essential, however, that the ceilometer data be fully integrated with the observations from the rest of the MET systems for operational use and for inclusion in METAR and SPECI reports.

The standard AWOS-3 observing system, as discussed above, is recommended for every controlled airport, and may optionally be installed at selected uncontrolled airports as well.

The specified AWOS-3 observing system represents a very high standard for MET observation. There are, however, additional sensors that are frequently used to further augment the observations. EarthSat's recommendations for a more limited CORE system are based on a decision to try to install the same basic observing station at all Colombian controlled airports in a cost-effective way. Additional sensors that can be integrated AWOS-3 class systems include a "present weather" or "precipitation identifier" sensor, an automatically recording raingage, and a thunderstorm identifier. As funding permits, these additional sensors could be added to enhance the standard AWOS-3 configuration, but should not be substituted in place of any of the standard AWOS-3 sensors. If UAEAC decides to install a National Lightning Detection Network, the thunderstorm sensor would not be needed at each airport.

The airports at Bogotá and Ipiales are high elevation airports. While snow and subfreezing temperatures are generally not a problem in Colombia, UAEAC may wish to evaluate if these two airports would benefit from the inclusion of sensor heaters and deicers to permit full operation of the weather stations in subzero temperatures.

In addition to the standard AWOS-3 weather station, there are a number of airports that require additional specialized MET observational systems. Airports with ILS runways need to be equipped with RVR and ceilometer systems. These systems are often installed as stand-alone systems linked directly to displays in the control tower or TRACON, but need to be integrated with the AWOS-3 system so that the ceiling and RVR values can be automatically incorporated into the hourly METARs.

Several Colombian airports are troubled by turbulent air and terrain-induced wind shear. EarthSat recommends that UAEAC address the problems encountered at these airports by installing an extended set of automatic wind measurements at the airport and on nearby terrain features. These "windshear" enhanced systems will necessarily be custom installations with special displays and enhanced provisions for data archive and playback. These systems should be build around a standard AWOS-3 class observing station to maintain a uniform basic national aeronautical observational system.

Installation of a National Lightning Detection Network will require the placement of sophisticated lightning sensors that are well distributed geographically across the country. At present, we estimate that this Colombian NDLN will require 25 additional sensors to augment the existing local lightning detection network operated by ISA. To achieve the required geographical distribution and coverage, some of the sensors will have to be installed at uncontrolled airports.

In order to make full use of the new MET observing systems, it is essential that all MET observations at each airport be fully integrated in a central processing system that can monitor the airport observations, evaluate data quality, and prepare comprehensive reports and climatologies. Automation without integration is a step backwards.

Airports that require special ILS and windshear systems will present a major challenge for integrating the weather information. These airports are identified in the right-hand column of Table A-3. Trying to integrate the output from a variety of sensors from different vendors can be problematic. A better approach is to either add the new sensors within an existing vendor's installed system, or to replace the old airport observing systems with new ones that are compatible with each other. If the old sensors are still functioning, they can be refurbished and reinstalled at other airports. This approach is a cost-effective way to ensure that the high priority airports have modern, reliable meteorological systems since the largest airports are generally the ones that have special integration requirements.

Performance standards for meteorological observation systems and products are discussed in ICAO's Annex 3, Attachment B, titled "Operationally Desirable and Currently Attainable Accuracy of Measurement or Observation" and Attachment C, titled "Selected Criteria Applicable to Aerodrome Reports." Hardware and system requirements for U.S. AWOS systems are described in detail in FAA Advisory Circular No. 150/5220-16C (FAA, 1999).

Requirements for timely, reliable reports are a major driving force for automated observations and reports that can be continued around the clock.

Table A-4: Meteorological Infrastructure Options and their Contribution to Recommended and Required Meteorological Products.

Table A-4 summarizes the contributions of the recommended infrastructure enhancements to each of the various recommended and required meteorological products.

All major infrastructure options identified in being included in the "Core Program" or suggested as "Recommended Program Enhancements" are listed in the left-hand column. The other columns list the main "in-route" and "airport and terminal area" MET products as discussed in Working Paper Number 1, and in Tables A-1 and A-2 (this appendix).

Each recommended option is evaluated as to its importance in contributing to each MET product.

Table A-4: Meteorological Infrastructure Options and their Contribution to Recommended and Required Meteorological Products

RECOMMENDED OPTIONS	RADIOSONDES	IN-ROUTE PRODUCTS								AIRPORT & TEMINAL AREA PRODUCTS			
	TEMPs	Situational Awareness	SIGMETs	AIREPs	Area Forecasts	Route Forecasts	MET BRIEFING	Support AFTN & GTS	ACC Operations	AIRPORT [illegible]	[illegible]	METAR [illegible]	TAF
CORE PROGRAM													
Basic Control Tower MET Systems										✓			
Upgrade Airport Surface Weather Stations		✓✓			✓✓	✓	✓✓	✓✓✓	✓	✓✓✓	✓✓✓	✓✓✓	✓✓
RVRs & Ceilometers for ILS Runways		✓✓			✓✓	✓	✓✓	✓		✓✓✓	✓✓✓✓	✓✓✓	✓✓✓
GOES Reception and Processing Upgrade		✓✓✓	✓✓✓	✓	✓✓	✓✓✓	✓✓✓		✓✓✓	✓✓			✓✓✓
Radiosonde Upgrades	✓✓✓	✓✓✓	✓✓✓		✓✓✓	✓✓✓	✓✓	✓✓✓	✓✓	✓			✓✓✓
WAFS Reception & Workstation		✓✓✓	✓✓		✓✓✓	✓✓✓	✓✓		✓✓✓	✓			✓✓✓
Airport MET Networking	✓✓	✓✓				✓	✓	✓✓✓		✓✓	✓✓	✓✓	✓
Forecaster Data Integration		✓✓✓	✓✓	✓	✓✓✓	✓✓	✓✓		✓	✓✓			✓✓✓
Software Templates (SIGMET & AIRREP)		✓✓	✓✓✓	✓✓✓		✓✓✓		✓✓	✓✓✓	✓			✓
Pre-flight Briefing System		✓✓✓					✓✓✓		✓✓	✓✓	✓		
Briefing Workstations for Airports and ATC		✓✓✓					✓✓✓		✓✓✓	✓✓	✓		
Communications Upgrades	✓✓	✓✓✓	✓	✓✓✓	✓✓	✓✓	✓✓✓	✓✓✓	✓✓	✓✓	✓✓	✓✓	✓✓
PROGRAM ENHANCEMENTS													
National Lightning Detection Network		✓✓✓	✓✓✓	✓	✓✓✓	✓✓✓	✓✓✓		✓✓✓	✓✓		✓	✓✓✓
Doppler Weather Radar		✓✓	✓✓✓	✓	✓✓	✓✓	✓✓✓		✓✓	✓✓			✓✓✓
Enhanced Windshear Montering Systems		✓✓	✓	✓✓	✓	✓	✓✓		✓	✓✓✓		✓	✓✓✓
Colombian Mesoscale Model		✓✓✓	✓		✓✓✓	✓✓✓	✓✓✓		✓✓✓	✓	✓		✓✓

Contribution Key	
✓	Small Contribution
✓✓	Major Controbution
✓✓✓	Critical Contribuluion

APPENDIX B

Aeronautical Meteorological Infrastructure: A Ten Year Phased Development Plan and Recommended Installation Schedule.

This Appendix presents a concise summary of the upgrades and enhancements recommended for Colombian airports over the ten-year phased development plan.

The following implementation plan and recommended schedule of upgrades takes into account UAEAC's assessment of each airport's importance within the Colombian aviation environment and it's internal priorities for the funding of airport and system enhancements, while also considering the existing condition of airport observational systems and the need for surface observations that cover all areas of Colombia.

In general, Colombia's main airports already have the best MET equipment. Recent upgrades, notably the installation of 12 Sutron weather stations in 2003 were preferentially installed at high UAEAC category airports. While we are recommending additional system enhancements, we don't want to rush to replace or upgrade these recently installed systems. We recommend that the new AWOS-3 systems that we are recommending be initially installed at slightly lower priority airports to ensure that the systems perform as expected and to work out potential problems with communication links and system integration. Airport weather systems serve two purposes. First and foremost, airport weather observations support local airport operations. At the same time, however, they also provide a national data base of observations that are critical to forecasters making regional and national weather forecasts. For national forecasts you need to have good a geographical coverage of surface observations.

Our implementation plan tries to balance the need to provide high quality weather observations at all controlled airports, while improving geographical coverage, and limiting the disruption of services at the major national airports.

In addition to the need to update the routine airport meteorological observing systems, Colombia also needs to respond quickly to provide all required RVR and ceilometer systems needed to support International and ILS airports. A critical factor in these enhancements is system and data integration. RVR and ceiling data needed to be included in METARs and not just displayed for ATC real time use. Similar integration issues are central to the windshear enhanced observing systems needed at Pasto and other airports. Integration requires prior planning, before proceeding with individual system procurements.

In some cases it may be possible for an existing weather station vendor to be able to integrate a new RVR or ceilometer as part of an upgrade to their basic system, but this will often require custom system enhancements and upgrades. Some vendors, such as Vaisala, have their own airport integration product that they use as a framework for all their sensor communication and displays. For airports that already installed components using this sort of integration environment it may be more efficient to replace incompatible sensors with new systems and transferring the older system to another airport

The proposed implementation schedule also highlights the installation of lightning detectors, but these sensors are part of a separate national system and don't have the same local airport integration requirements. In particular, there is no need to install the lightning sensors at the same time that the airport surface weather systems are upgraded.

In proceeding with the implementation plan it is critical to conduct a careful, comprehensive evaluation of system power requirements and communication needs. In particular, there is a general need to provide specific weather systems such as RVR and ceilometers with AC line power and communication links are critical to all the recommended upgrades.

The airport systems installation schedule is tentative and somewhat hypothetical. It provides a concrete starting plan, but needs to be reviewed and updated before execution.

Tentative Airport Systems Installation Schedule

Current Weather Stations

Twelve (12) Sutron systems installed in 2003, designated as "S12" systems.

New Weather Stations that were ordered in 2004.

Four (4) newer model Sutron systems with improved software and additional visibility and present weather sensors. These systems need to add a ceilometer to bring them up to EathSat's baseline recommended system. The "present weather" sensor is beyond our recommended specification. For routine AWOS installations, the ceilometer may be installed at a separate location than the rest of the system to permit easier access to line power. For reference, these systems will be designated as "NS". It is assumed that the NS systems will be installed in mid-2005, at

Popayan
Barrancabermeja
Santa Marta
Ibaqué.

<u>Year 1, 2005</u>

Acquire four (4) additional new AWOS systems based on the EarthSat recommend configuration. These AWOS-3 systems should be installed at:

Quibdo
El Yopal
Monteria
Aruca

Test systems, test communication upgrades.

Install 2 replacement RVR systems and 1 ceilometer at **Bogotá's El Dorado** airport, plus 1 ceilometer at **Cali**. Evaluate the need for adding heaters for deicing the El Dorado weather systems.

Begin communications upgrades and power improvements as needed to support future AWOS-3, RVR, ceilometer, and lightning sensors installations.

Year 2, 2006

Acquire custom, extended airport wind monitoring system (windshear), to be integrated with a new, standard AWOS-3 configuration system with custom displays and RVR instrumentation, at:

Pasto.

Install a new AWOS-3 system with enhanced capabilities at **Medellin** (EOH). Recommended enhancements to the standard AWOS-3 configuration include a present weather sensor with wind and visibility measurements being made at each end of the runway; supported by custom weather displays for ATC. This custom configuration could be assembled from existing Sutron systems transferred from Rionegro and Cali, with the addition of new software, a ceilometer, and two visibility sensors.

Upgrade software, displays, and add ceiling and visibility sensors at six of the S12 installation sites.

Leticia*
Rionegro*
Cali*
Barranquilla*
Cucuta*
San Andres**

All of these airport systems will need to integrate their upgraded AWOS systems with their new RVR systems (see below).

Install new forward-scatter RVR systems at **Leticia**, **Baranquilla**, **Cucuta**, and **San Andres** as part of an integrated airport weather system. Integrate the existing RVR and ceilometer systems at **Cali** and **Rionegro**, perhaps building on the Vaisala MIDAS IV airport weather systems already installed at these airports. With a MIDAS IV solution, it may be cost effective to transfer the existing Sutron systems at these two airports to Medellin, and acquire new Vaisala weather instruments for use with the MIDAS IV integration environment.

Begin installing Lightning Detection Network sensors at designated airports. Preliminary plans suggest installing five (5) lightning detectors in 2006, at the controlled airports at *Quibdo*, *Carepa*, *Monteria*, and *El Yopal* and at the uncontrolled airport at *El Banco*.

Add METARs to the AeroCivil network (domestic use only) from the existing AWOS-3P/T systems operating at private airports owned by the El Cerrejón mine. This is a data access and integration issue since the observing systems are already installed at:

La Mina
Puerto Bolivar

Year 3, 2007

Upgrade surface weather systems at **Bogotá's El Dorado Airport**. Upgrade systems as required and integrate entire system for automatic METARs, including RVR. Evaluate the need for adding heaters for deicing of the El Dorado weather systems.

Add ceilometers to the four (4) NS stations at:

Popyan
Barrancabermeja
Santa Marta
Ibague

Acquire and install two (2) additional new AWOS-3 systems for the airports at:

Mitu
Carepa

Install additional Lightning Detection Network sensors at ten (10) designated airports. Preliminary plans suggest the sensors be installed in 2007 at the controlled airports at *Valledupar*, *Riohacha*, *Arauca*, *Puerto Carreño*, *San José del Guaviare*, *Villavicencio*, and *Mitu* and the uncontrolled airports at *Las Gaviotas*, *Puerto Inirida*, and *Barrancomina*.

Year 4, 2008

Upgrade software, displays, and add ceiling and visibility sensors at three S12 installation sites.

Cartegena**
Bucarranmanga**
Villavicencio

Two of these airport systems (Cartegena and Bucarranmanga) will need to integrate their upgraded AWOS systems with new or existing RVR and ceilometer systems (see below).

Install RVR systems integrated into upgraded AWOS-3 systems at **Cartegena** and **Bucarranmanga**.

Acquire and install two (2) additional new AWOS-3 systems for the airports at:

Nevia
Tumaco

Install additional Lightning Detection Network sensors at ten (10) additional airports. Preliminary plans suggest the sensors be installed in 2008 at the controlled airports at *Leticia*, *Puerto Asis*, *San Vicente del Cuguan*, *Popayan*, *Tumaco*, and *Armenia* and at the uncontrolled airports at *Araracuara*, *La Pediera*, *Arica*, and *Puerto Leguizamo*.

Year 5, 2009

Perform a comprehensive upgrade (or replace) the Qualimetrics AWOS-1 systems (Qualimetrics is currently owned by "All Weather, Inc.") to bring them up to the recommended AWOS-3 configuration at:
Puerto Inirida
San Jose Del Guaviare

Install an RVR system, fully integrated into the upgraded AWOS-3 system at **San Jose del Guaviare**. .

Upgrade software, displays, and add ceiling and visibility sensors at the S12 installation site at:. **Pereira**

Acquire and install one (1) additional new AWOS-3 system for the airport at: **Puerto Carreña**

Year 6, 2010

Acquire a custom, extended airport wind monitoring system (windshear), to be integrated with a new, standard AWOS-3 configuration system with custom displays. To be installed at:
Providencia.

Upgrade software, displays, and add ceiling and visibility sensors at two (2) more S12 installations:
Manizales
Guaymaral

Acquire and install two (2) additional new AWOS-3 systems for the airports at:
Puerto Asis
Bahia Solano

Year 7, 2011

Acquire and install four (4) additional new AWOS-3 systems for the airports at:
San Vicente del Caguan
Riohacha
Armenia
Valledupar

Year 8, 2012

Enhance the existing AWOS-3 weather system at **Buccaramanga** to integrate additional airport wind sensors for monitoring wind shear, and update the system displays to accommodate the additional wind data.

Acquire and install five (5) additional new AWOS-3 systems for the airports at:
Ocana
Cartago
Ipiales
Buenaventura
Girardot

Evaluate the need for adding heaters for deicing of the weather systems being installed at Ipiales.

Year 9, 2013

Acquire and install four (4) additional new AWOS-3 systems for the airports at:

Mariquita
Florencia
Corozal
Guapi

Year 10, 2014

Acquire and install two (2) additional new AWOS-3 systems for the airports at:

Saravena
Tame

To enhance the geographical coverage of MET observations over eastern Colombia, optionally acquire and install two (2) additional new AWOS-3 systems for the uncontrolled airports at:

El Banco
Araracuara

Phase II, 2015+

To enhance the geographical coverage of MET observations over southeastern Colombia, optionally acquire and install four (4) additional new AWOS-3 systems for the uncontrolled airports at:

Barrancomina
La Pediera
Puerto Leguizamo
Arica

Additional Lightning Detection Network sensors may be needed to extend areas of coverage. Possible additional installation sites include the controlled airports at *Bahia Solano*, *San Andres*, and *Providencia*. The island sites would only be appropriate as part of a Central American Lightning Network in collaboration with Nicaragua. The site at Bahia Solano would also enhance a Central American Network by extending coverage over the Golfo de Panamá, in collaboration with Panamá. Coverage over southeasten Colombia could be enhanced by additional sensor sites at *Miraflores* and *Tarapaca*.

During Phase II, all Colombian AWOS-3 systems would benefit from being upgraded with present weather sensors and recording rain gages.

Working Paper Number 3

RECOMMENDED MANAGEMENT AND ORGANIZATIONAL STRUCTURE FOR A MODERNIZED COLOMBIAN AERONAUTICAL METEOROLOGICAL SYSTEM

Prepared for

Unidad Administrativa Especial de Aeronáutica Civil
Aeropuerto El Dorado
Bogotá, Colombia

by

Earth Satellite Corporation
Peak Weather Resources
National Center for Atmospheric Research

February 2005

EARTHSAT

Table of Contents

1 Introduction

The objective of aeronautical meteorological services is to contribute towards the safety, regularity, and efficiency of international and domestic air navigation. This objective is to be achieved by supplying operators, flight crew members, air traffic services units, search and rescue services units, airport managements, and others concerned with the conduct or development of international and domestic air navigation, with the meteorological information necessary for the performance of their respective functions.

Colombia is responsible for determining the meteorological service it will provide to meet the needs of its international and domestic air navigation system. **Colombia has named the Unidad Administrativa Especial de Aeronáutica Civil (UAEAC, also termed AeroCivil) as the Designated Meteorological Authority** to provide or arrange for the provision of meteorological services for international and domestic air navigation on its behalf. Such a provision of services should, of course, be made in accordance with pertinent documents of the International Civil Aviation Organization (ICAO), the World Meteorological Organization (WMO), the Caribbean/South American (CAR/SAM) Regional Air Navigation (RAN) Plan, and *Document 8733, Version 14* which includes the basic Air Navigation Plan (ANP) and the Facilities and Services Implementation Document (FASID). References to these documents are listed in Appendix A. Requirements from these documents have been cited in Working Papers 1 and 2.

The contract language for the current work states the task as follows: "*Working with the UAEAC, the Consultant will review the organization and management structure of UAEAC and other institutions which provide aeronautical meteorology services in light of the recommended modernization plan and make suggestions regarding changes in organizational or management structure to enhance the provision of aeronautical meteorology services and meteorological phenomena research in order to prevent aeronautical meteorology adversities*." This effort has been conducted according to the following stages.

The initial steps were accomplished through a concerted effort by the EarthSat Team to develop Working Papers 1 and 2. The final step under this task is the review of the organizational structure and identification of a modernization plan that includes a revised organizational structure and an accompanying training plan. To accomplish this, the present Working Paper Number 3 builds on the results previously reported in Working Papers 1 and 2. It includes material developed through specific references to on-site visits, personal interviews, and a thorough examination of documentation of required and proposed plans. It reviews the strengths and weaknesses of the current aeronautical meteorological system, makes recommendations for changes to bring the system into compliance with the regulatory infrastructure, and suggests phased improvements for the future.

2 Review of Operational Requirements for Aeronautical Meteorology

Working Paper 1 described the diverse geography of Colombia and the importance of aviation to the citizens. The weather (aviation impact variables) affecting the aeronautical operation has also been described in Working Paper 1. The ability to forecast, warn, and distribute information about aviation impact variables will be the main emphasis of any proposed organization.

Operational requirements have been cited in Working Papers 1 and 2. Colombia has a responsibility to the international aviation community and to domestic aviation operators to meet its requirements. In this section we briefly review these requirements and objectives, and in the following sections propose, accordingly, a modernization plan for aviation weather services in Colombia.

2.1 ICAO standards and recommendations

Contracting states to the ICAO Chicago Convention can report any differences between their national regulations and practices and the international standards and recommended practices of Annex 3 and its approved amendments. Colombia has not filed any notices of differences between their regulations and procedures and those of Annex 3, implying that Colombia accepts Annex 3 standards and procedures. ICAO's Safety Audit program for MET Services (ICAO Document QMSF-007-12) was not available and has not been filled out as far as the EarthSat Team could ascertain. The following discussion concerning the structure of the Colombia aeronautical meteorological system is based on the premise that Colombia shall meet all provisions of the services to which it has agreed.

2.1.1 Meteorological Offices

AeroCivil is responsible for providing meteorological office(s) that are adequate for the provision of the meteorological service required to satisfy the operational needs for designated airdromes. Section 3.4 of Chapter 3 in ICAO Annex 3 describes the functions necessary to meet the needs of flight operations at an aerodrome. Each meteorological office shall carry out all or some of the following functions:

a) Prepare and/or obtain forecasts and other relevant information for flights with which it is concerned.
b) Prepare and/or obtain forecasts of local meteorological conditions.
c) Maintain a continuous survey of meteorological conditions over the aerodromes for which it is designated to prepare forecasts. (The Bogotá office has the responsibility to maintain a continuous survey of the meteorological conditions.)
d) Provide briefing, consultation, and flight documentation to flight crew members and/or other flight operations personnel. (Flight documentation is

prepared at seven meteorological offices utilizing local resources and the resources of the Bogotá office.)

e) Supply other meteorological information to aeronautical users.
f) Display the available meteorological information.
g) Exchange meteorological information with other meteorological offices.
h) Supply information received on pre-eruption volcanic activity, a volcanic eruption or volcanic ash cloud, to its associated air traffic services unit, aeronautical information service unit, and meteorological watch office as agreed between the meteorological, aeronautical information service, and ATS authorities concerned.

The above functions are detailed by the Regional Air Navigation (RAN) meetings and published in two volumes: a regional basic air navigation plan (ANP), and a facilities and services implementation document (FASID). These agreements may also be expanded by supplementary agreements between the meteorological authority and the operator concerned. The aerodromes for which meteorological observations and landing forecasts are required are specified in the Basic ANP and FASID. For aerodromes without meteorological offices, the meteorological authority designates one or more meteorological offices to supply meteorological information as required and establishes a means by which such information can be supplied to the aerodromes concerned. Details of the CAR/SAM Basic ANP and FASID documents specifying the international meteorological responsibilities of the Republic of Colombia are discussed later in Section 2.2 of this Working Paper.

2.1.2 Meteorological Watch Offices

Having accepted the responsibility for providing air traffic services within its two flight information regions (FIR) or control areas, Colombia is obligated to maintain one or more meteorological watch offices, or to arrange for another contracting state to do so. The office designated to be the Meteorological Watch Office (MWO) in Colombia is the Bogotá office located at the El Dorado Airport (SKBO). The responsibilities of the SKBO MWO are:

- Maintain watch over meteorological conditions affecting flight operations within its area of responsibility
- Prepare SIGMET and other information relating to its area of responsibility
- Supply SIGMET information and, as required, other meteorological information to associated air traffic services unit(s)
- Disseminate SIGMET information.

When required by the Regional Air Navigation Agreement, Colombia is obligated to:

- Prepare AIRMET information related to its area of responsibility
- Supply AIRMET information to associated air traffic services units
- Disseminate AIRMET information

- Supply information received on pre-eruption volcanic activity, a volcanic eruption and volcanic ash cloud for which a SIGMET has not already been issued, to its associated ACC/FIC, as agreed between the meteorological and ATS authorities concerned, and to its associated volcanic ash advisory center as determined by RAN
- Supply information received concerning the accidental release of radioactive materials into the atmosphere.

SIGMETs are issued by SKBO MWO on occasion for volcanic ash. There is little evidence to suggest that SKBO MWO is issuing SIGMETs for the other en-route weather hazards including thunderstorms, tropical cyclones, turbulence, severe mountain wave and in-flight icing. AIRMETs are not required by CAR/SAM (reference: Basic ANP, Part VI, paragraph 32). Therefore SKBO does not issue AIRMET information.

2.1.3 Volcanic Ash Advisory Center (VAAC)

Under the terms of the International Airways Volcano Watch, the Washington VAAC is responsible to provide SKBO MWO with specific ash advisories in the event of a volcanic eruption that has the potential to impact Colombian airspace. Because of the need for timely collaboration between the member states and the regional VAAC, Colombia has the responsibility to be the national liaison with Colombia's designated volcano observatories and to notify the VAAC of potential eruptions before they occur. After an eruption which has the potential to eject volcanic ash to elevations where they could impact air traffic, SKBO MWO should immediately issue a SIGMET announcing the eruption and contact the VAAC to notify them of the eruption. After receipt of a formal Volcanic Ash Advisory from the VAAC, SKBO MWO should issue a revised SIGMET in accordance with the VAAC's advisory. SKBO MWO should also notify the two air traffic control centers concerning the hazard as well as ensure receipt of a SIGMET.

Specific procedures and responsibilities with respect to volcanic eruptions are detailed in the ICAO *"Handbook on the International Airways Volcano Watch: Operational Procedures and Contact List."* The most recent version of this handbook (Second Edition, 2004) is available online at:

http://www.icao.int/icaonet/dcs/9766_2_en.pdf
http://www.icao.int/icaonet/dcs/9766_2_sp.pdf

for English and Spanish editions, respectively.

2.2 Regional regulations and agreements

While Section 2.1 describes the general ICAO and WMO recommended International Standards and Practices, many of the specific requirements for the provision of aeronautical weather services are governed by regional agreements within the Caribbean/South American (CAR/SAM) Region such as Document 8733 (Version 14) that details the Regional Basic Air Navigation Plan (ANP) and the Facilities and Services Implementation Document (FASID).

2.2.1 CAR/SAM Basic ANP and FASID

These documents list specific commitments by Colombia to provide aeronautical weather services from the meteorological offices and from SKBO MWO. Strictly speaking, these commitments are only relevant to designated international airports, but the services provided will usually be needed for domestic flights as well. In Part VI, "Meteorology," the Basic ANP document effectively defines a minimum standard for all CAR/SAM for MET facilities and service.

In an appendix to Part III, the Basic ANP document identifies eight international airports for Colombia (see list below in Table 2.1). FASID Met Table 1A specifies that each of these airports will be provided TAFs, and Met Table 2A specified that (except for Cúcuta) these airports will disseminate TAFs and METARs to a specified list of international airports. With the exception of Leticia and Cúcuta, these airports are identified (FASID, Table MET 1A and Table AIS 2) as being used regularly for international scheduled air transport. Leticia and Cúcuta are identified as being used regularly for non-scheduled international air transport and use as international alternate airports.

Table 2.1 International airports in Colombia

City	Airport
Barranquilla	Ernesto Cortissoz
Cali	Alfonso Bonilla Aragón
Cartagena	Rafael Núñez
Cúcuta	Camilo Daza (METARs, TAFs not disseminated)
Leticia	Alfredo Vásquez Cobo
Rionegro	José Maria Córdoba
San Andrés I.	Sesquicentenario
Bogotá	El Dorado

These airports also have Aeronautical Information Service Units (FASID, Table AIS 2) and provide weather briefing, consultation, and flight documentation services to flight crew members or other operations personnel.

FASID Met Table 1B identifies a single MWO serving all of Colombia.

Bogotá/El Dorado

This MWO is responsible for providing a MET watch over the Bogotá FIR/UIR/SRR and the Barranquilla FIR (below FL200). This MWO is also responsible for issuing SIGMETs. The MWO receives tropical cyclone advisories from the Tropical Cyclone Advisory Centre in Miami and volcanic ash advisories from the Volcanic Ash Advisory

Centre in Washington. Volcanic Ash Advisories are also sent to the Barranquilla Control Center.

Airport-by-airport details of the services provided at Colombian airports are available on the AeroCivil web site as part of the Aeronautical Information Publication (AIP) specified in ICAO Annex 15. The web resource provides detailed information for domestic as well as international aerodromes. A full listing of controlled Colombian airports and available services is also presented in Table 4.1 of Working Paper 1.

2.2.2 CAR/SAM Regional Plan for CNS/ATM Systems

The CAR/SAM Regional Plan for the Implementation of the CNS/ATM Systems (ICAO, 1999) discusses the ways that meteorological services in the CAR/SAM region will have to change to support the evolutionary transition to the new generation of ATM systems. The need to improve meteorological information has been discussed in Working Paper 1.

Working Paper 1, Section 4.6, has described the present CNS/ATM system in Colombia and required improvements consistent with the CAR/SAM Regional Plan. Future enhancements to the meteorological systems within the overall CNS/ATM system will provide wider access, both in-country and internationally, to more observations and forecasts. Operationally, this will require increased use of automated systems. While humans will usually still be involved in the data collection, their role will move to being more of a sophisticated user monitoring the observations for data quality before they are distributed, and not having to make manual data entries or retype products for multiple transmissions. At the same time, the regional implementation plan calls for the development of automated AIS/MET pre-flight briefing facilities and products that will provide an enhanced situational awareness of Colombian and Regional weather systems and hazards. These changes will have a major impact on individual job responsibilities and require, additionally, a significant commitment to advanced training and further education of meteorological staff.

The transition to the new CNS/ATM systems will have to be accompanied by new observational systems and capabilities. These new systems will frequently be based on remote sensing capabilities including satellite observations, meteorological radars, lidars, and lightning detection systems, and will be used in conjunction with mesoscale numerical models, SIGMETs and (AIRMETs if required) to produce the enhanced situational awareness that is needed for effective pre-flight briefings, air traffic control, and dispatch operations.

Working Paper 2 has discussed the need to make full use of Air-reports from pilots, integrating their observations into the Colombian aeronautical meteorological system. These Air-reports (termed AIREPs internationally, and PIREPs within the United States) provide valuable alerts to hazards such as turbulence and in-flight icing. If the hazards are anticipated to be long-lasting and cover a significantly large area, the AIREPs may also lead to SIGMET reports being issued. AIREPs can also be key components for preparing forecasts. For example, a new program has been developed at the U.S.

Aviation Weather Center in Kansas City to facilitate the transfer of air-reports by allowing airline dispatchers to enter AIREP reports from their airline's aircraft into the national database. This data enhances the Aviation Weather Center forecasters' knowledge of the three dimensional structure of the atmosphere, adds valuable data to automated algorithms that forecast turbulence and thunderstorms, and creates a situational awareness for operators, flight crew members, air traffic services units, and other aeronautical users. Figure 2.1 (below) shows an example of the AIREP reports of turbulence (termed PIREP reports in the U.S.) collected at 1800Z on 27 January, 2005. Note the reports of moderate severe turbulence over the northwestern United States, and also note the large number of reports indicating that the aircraft were not experiencing any turbulence, allowing aviation weather forecasters to better identify the limits to the airspace for which AIRMETs or SIGMETs might be issued.

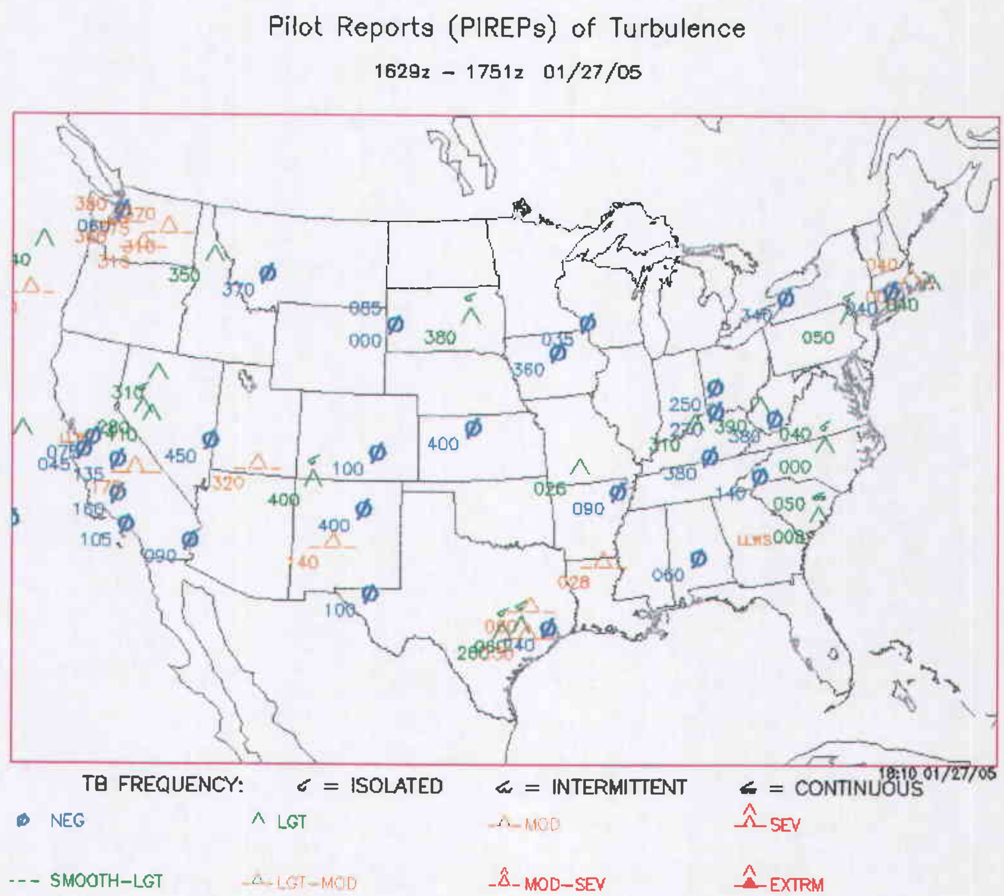

Figure 2.1. The graphic shows a snapshot of pilot reports over the contiguous United States available to the forecasters at the AWC in Kansas City and also available to pilot weather briefers at FAA flight service stations as well as air traffic controllers, private distributors and pilots.

The hallmark of the new meteorological systems will be faster response times to time-critical hazards such as pilot reports of turbulence or volcanic eruptions.

With the ability to distribute more observations and local products and warnings, there will be a need to update and expand the regional FASID agreements to reflect these new capabilities and new requirements.

2.3 Colombian National Agreements

The provision of Aeronautical Meteorological Services began under the authority of the Administrative Department of Civil Aviation (DAAC). The provision of other meteorological services was through the Colombian Hydrological and Meteorological Service. Within the Meteorological Service agency, the Institute of Hydrology, Meteorology, and Land Adaptation (HIMAT) was created, subsequently known as the Instituto de Hidrología, Meteorología y Estudios Ambientales (IDEAM), collectively The Colombian National Meteorological Service (NMS).

As stated in Section 1, the Designated Meteorological Authority for the provision of aeronautical meteorological services in the Republic of Colombia is AeroCivil. AeroCivil is the official ICAO representative. AeroCivil has made a conscious decision to meet the responsibilities of the provision of services through a joint agreement with IDEAM.

Appendix A is the English translation of the joint agreement.

3 Organizational Structure in Colombia and Contrasting Examples in Other Countries

3.1 Current Organizational Structure in Colombia

One of the prominent features of the Colombian Aeronautical Meteorology System is its dependence on shared management and shared responsibility. While AeroCivil is the official ICAO representative and has the responsibility for providing Aeronautical Meteorological Services in Colombia, AeroCivil provides these services through a joint agreement (see Appendix A) with IDEAM — the national meteorology authority to the WMO. IDEAM provides most of the meteorological expertise, including the forecasting staff at the SKBO MWO and virtually all of the full-time MET observers at Colombian airports. As summarized in Working Paper 1, Table 4.1, IDEAM staff prepares METARs at 27 of Colombia's 48 controlled airports, with AeroCivil staff preparing METARs at 18 of the smaller airports that do not have full time MET observers.

At present, the Colombian aeronautical meteorology system has a parallel structure with considerable duplication of components (see Working Paper 1).

It is not unusual for a country to have separate weather agencies, one within a civil aviation authority and another as the country's main meteorological agency (e.g., for weather forecasting, hydrology, climatology, and environmental concerns). However, in most countries, one entity within the country provides the aeronautical meteorological services. Section 3.2 summarizes how aeronautical meteorological services are provided by a selection of countries. Colombia is unusual in that the provision of aeronautical meteorological services is split between IDEAM and AeroCivil, with each agency performing specific services on an airport-by-airport basis.

In Working Paper 2, EarthSat recommends that AeroCivil maintain the responsibility for providing all the basic airport observing systems, including meteorological observations and measurements, so that there can be a clear sense of responsibility and simplify the full integration of the meteorological systems into the airport infrastructure, communication links, and operational support.

In Working Report Number 1, EarthSat reviewed the current Colombian Aeronautical Meteorology System and identified a number of deficiencies. A minimal service is available based on the existing IDEAM –AeroCivil agreement, but the service falls below international standards in a number of respects and there is no effective distribution of the aviation weather information. Meteorological services in Colombia have not kept up with the user requirements, which in general exceed the official requirements.

In the report, "Results of consulting advice" (ISI, 2003), there is further confirmation of the findings that the EarthSat Team made concerning perceived lack of information available to the aeronautical user community, we quote, *"When talking with the airlines it soon became obvious that Colombia does not have an established functioning system anywhere in the country that they use. There is no TV weather person or any place a pilot can get forecast weather for any airport in Colombia. Several people told us they get it from the Internet but when they showed us how they obtained this information is was always CNN and useless for use in aviation except to show where some clouds were. Because every pilot must have enough fuel on every flight to return to his base a great deal of money is wasted in carrying extra fuel on every flight.*

We witnessed this first hand flying from Bogotá to Medellin. We took off and 23 minutes later we were told that we would be returning to Bogotá. After the flight we talked with the pilots. We asked them why they did not have accurate weather information 20 minutes earlier. They did not have any information telling them that their destination airport was closed because of weather and they said they never have any information. They just take off and when they start on the approach are told if the field is below minimums. If it is below minimums they return to the airport they took off from. The weather at most airports seems to be worse in the morning.

Colombia aviation will save millions a year if they can get reliable weather forecasting for use by the airlines at airport destinations."

Neither IDEAM nor AeroCivil takes full responsibility for the program and there appears to be a fundamental disconnect in forecasting philosophy between the two agencies. There also appears to be a divergence of opinion between IDEAM and AeroCivil with regard to which agency is in charge of certain functional and operational responsibilities. This leads one to conclude that the existing agreement is not sufficiently detailed to permit the identification of clear lines of authority and responsibility.

3.2 Examples of How other Countries Provide Aeronautical Meteorology Services

Before suggesting possible modernization solutions for establishing a modern service in Colombia, it is of interest to look at other models from around the world to see how meteorological services are delivered elsewhere.

The aviation business was much simpler 50 years ago. However, one reason that life may have been simpler was the fact that many of the services that needed to be provided to the international air carriers were not being provided. The two graphics below courtesy of the METSERVICE of New Zealand shows how aviation forecasting has changed in the last 50 years.

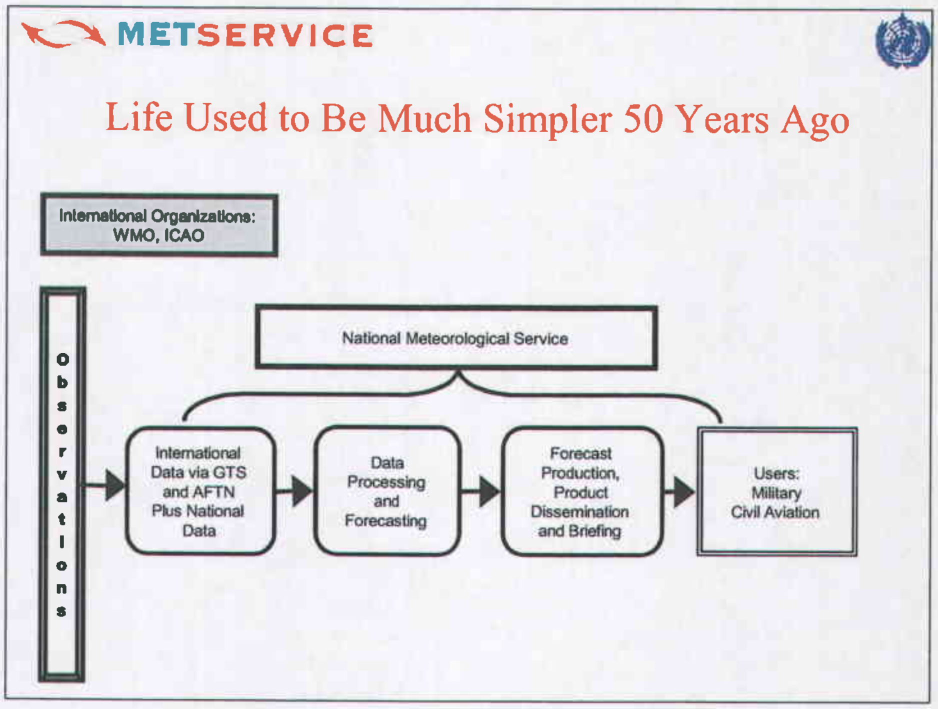

Figure 3.1 The graphic depicts all the players in the Aeronautical Meteorological Forecasting activity some 50 years ago.

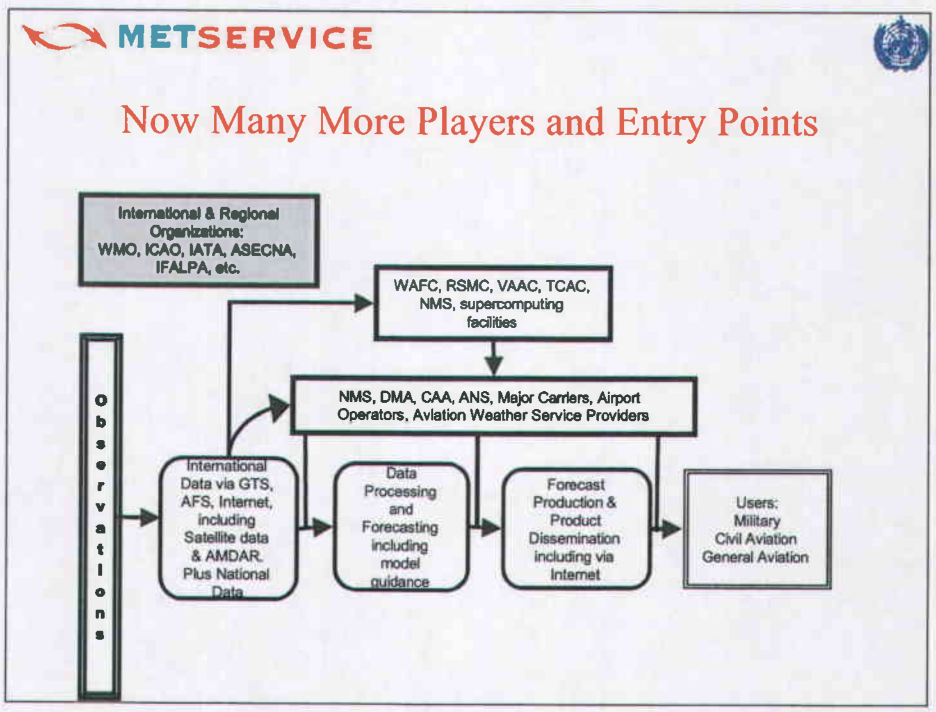

Figure 3.2 In comparison with Fig. 3.1, the number of players has increased dramatically and the end products have many more factors to depend on.

In over half of the world today, aviation weather services are funded through the principle of cost recovery. A 2003 survey done by the WMO, for which 102 out of 187 countries replied, showed that 59% of meteorological service providers recover costs. Of those that do not at present, 55% are planning to recover cost and another 38% are considering it. By using cost recovery, countries are able to meet all of the international and domestic requirements for aviation without having to depend on federal budget dollars. Aviation historically has been a significant user of meteorological services, and many countries consider it appropriate that aviation users pay accordingly. ICAO Doc. 9802/7 "Statements by the Council to Contracting States on Charges for Airports and Air Navigation Services and ICAO Doc. 9161-AT/724 "Manual on Air Navigation Services Economics" (Appendix 6) provide the basis for the fee charges that countries use for cost recovery. In a reply to a query to all nation states from ICAO, Colombia in April 2002 stated, "*At present, Colombia is developing a cost system to fix tariffs in accordance with the principles of Document 9082/6 and with the provisions contained in the manuals on the economic aspects of Airports on Air Navigation Services.*" A key statement in ICAO Doc.9802/4- Statements by the Council-Statement 35 (ii): "*It is for each state to decide for itself whether, when and at what level any air navigation services should be imposed, and it is recognized that States in developing regions of the world, where financing the installation and maintenance of air navigation services is difficult, are particularly justified in asking the international airlines to contribute through user charges toward bearing a fair share of the cost of the services*".

The WMO provides guidance in the document WMO-No. 904, "Guide on Aeronautical Meteorological Services Cost Recovery." The WMO Guide provides a "how to" of principles, including assessing costs of providing aviation services (en-route and terminal area usually separated). Although ICAO principles strictly apply to international aviation only, the same approach can be used for domestic aviation. It is considered appropriate to include both "direct costs" of providing services to aviation, and a share of "infrastructure" costs. The Global "Conference on the Economics of Airports and Air Navigation Services" held from June 19-28, 2000 in Montreal, re-affirmed that it was appropriate to seek funds for services and infrastructure costs. There are four components of a cost recovery framework for aeronautical meteorological services. The first step in any country is to ascertain what entity is the Designated Meteorological Authority as this plays a critical role in terms of international obligations. The next three components are Service Delivery, Revenues, and Revenue Distribution.

The component of Service Delivery needs continuing consultation among stakeholders. There has to be clear agreement of what services are required, including those meeting international obligations and who is providing them. Any agreement should include:

- Deliverables
- Frequency and timing of information
- Standards to follow
- Performance measures
- Payment schedules
- Dispute resolution procedures.

Revenues are charges based on costs of providing the service. The first step is to make an inventory of facilities and services needed to service the different user/customer communities. Add to that the costs and human resources needed to carry them out, then determine the fair share of infrastructural costs as well as direct costs. As mentioned above, there is guidance from ICAO and WMO on how to compute these costs. Based on the guidance from ICAO and WMO, a method should be defined for allocating charges to different airlines and airplanes (en-route, terminal, plane size, etc.). An efficient mechanism for collecting the revenues also needs to be implemented. All of the above should be developed in consultation with the stakeholders.

Within the concept of revenue distribution, a strong contractual agreement with all parties for the appropriate redistribution of revenues should be prepared. This process entails a significant level of consultation and negotiation among the parties. It is appropriate that a portion of charges is identified to assist in maintaining the basic national infrastructure and international framework upon which aeronautical meteorological services are based.

In this philosophy of cost recovery with aviation paying for services, there is a direct line between the customer and the services provided. Aviation specifies the services and the countries deliver them as required. One advantage is that this type of arrangement provides less vulnerability to uncertainties in government funding. The dialogue regarding costs and services that is carried on between a civil aviation authority and its customers also leads to efficiencies in the overall program. The cost is relatively small (compared to other aviation costs such as fuel, etc.) and experience has shown that it leads to responsive service. Another advantage is that the costs are only aviation-related and are not subsidising other services. This distinction avoids implications that might otherwise arise in proposing a joint effort to provide weather services.

In the next few sections examples are presented describing how aviation services are provided in different countries. These include New Zealand, Canada, the United States of America, the European Community, and Taiwan. Other variations of service exist, but these examples are sufficient to illustrate the differences.

3.2.1 Aviation Meteorological Services provided by New Zealand

Until the 1980s, the provision of meteorological services in New Zealand was in the Ministry of Transport. During the 1980s there was increasing pressure on government funding for meteorology in New Zealand, together with a government-wide move to "user-pays" for specialized services, and to more autonomy and accountability for government departments. A combination of commercial competition in the deregulated market for meteorological services and reform of publicly funded science led to the establishment of two government-owned companies in July 1992. One of the companies, METSERVICE, is responsible for the provision of aeronautical meteorological services to civil and military aviation along with other core services. These services are provided on a fee basis.

The provision of aeronautical meteorological services is regulated by the New Zealand Civil Aviation Authority (CAA) under Rule Part 174. The CAA is the designated Meteorological Authority for ICAO. In brief, the objective of this rule is to provide the regulatory requirements for persons or organizations wishing to provide meteorological services in support of the New Zealand civil aviation air navigation systems. The rule also provides for the organizations to provide support to enable New Zealand's obligations under the ICAO Regional Air Navigation Plan to be discharged. Part 174 adopts the standard layout for the rule parts relating to the certification of organizations. The layout prescribes specific requirements for the certification (entry standards), operation (continued operations), and safety audit (surveillance) of persons providing aeronautical meteorological services. The provision of meteorological services to meet New Zealand's international obligations under the ICAO Regional Air Navigation Plans is subject to separate formal agreements between the CAA and the appropriate certificated meteorological service provider.

The aviation services provided by METSERVICE are on a wholly commercial basis and there are individual customer contracts. There is also a clear separation of the core meteorological services provided by New Zealand from the aviation services. Under Rule 174, METSERVICE provides aviation safety through following quality standards. These standards address personnel and training, the sites, facilities, and communications. They also address the record-keeping and manuals, and provide quality assurance procedures. As part of the Rule 174 process, regular audits are carried out. The separate business division is customer focused. There are aviation-literate forecasters in a separate forecasting section. The METSERVICE is competitive because other suppliers can also be certified under Part 174.

METSERVICE currently has separate contracts with domestic airlines, international airlines, air traffic control (Airways Corporation of New Zealand) and the Royal New Zealand Air Force. Approximately 25% of overall METSERVICE revenues come from the aviation contracts. (Private correspondence, Neil Gordon, President of Commission for Aeronautical Meteorology, WMO, METSERVICE New Zealand).

3.2.2 Aeronautical Meteorological Services provided by Canada

The country of Canada represents another model of how to provide aviation weather services but with some similarities to New Zealand. Until 1971, the Meteorological Service of Canada (MSC) provided all meteorological services and was part of the Department of Transportation (MacDonald, private paper, 2005). In 1971, the MSC moved to the newly created Department of Interior, but the Department of Transportation retained responsibility for the delivery of aviation weather services. MSC provided most aviation weather services under the terms of an interdepartmental memorandum of understanding with costs being recovered from the Department of Transport through an annual, negotiated, budgetary transfer. The designation as the Meteorological Authority to ICAO rested with the Department of Transport and not MSC.

In 1996, the government of Canada privatized the air navigation service. A non-shared capital corporation (NAV CANADA), formed by aviation stakeholders, was created and then negotiated the purchase of the air navigation system from the government for $1.5 billion Canadian. At that time, all responsibilities for operating the air navigation system including the provision of aviation weather services was transferred to NAV CANADA. NAV CANADA receives no government funding – it recovers its costs wholly from user fees. The Department of Transport has become the regulator of air navigation services and, with respect to meteorology, continues to be the designated Meteorological Authority to ICAO (although it is neither the provider of aeronautical meteorological services nor the national meteorological agency).

To ensure the continuity of quality weather services, the transfer legislation (the Civil Air Navigation Services Commercialization Act: 1996) obligated NAV CANADA to enter into a five-year contract with MSC for the provision of all services being provided by MSC at the time of transfer. That contract was renegotiated in 2001 for a further ten years.

The relationship between MSC and NAV CANADA is primarily a business relationship between a service provider and a client. A range of services required by NAV CANADA has been defined and the costs of providing these services have been calculated by MSC based on the principle of full-costing, i.e., to include indirect costs such as employee benefits, training, administration, and human resources support, etc. MSC and NAV CANADA negotiated on a cost basis, individual product and service prices. For example, a 24-hr TAF, issued every six hours, is priced at $37K Canadian per year. NAV CANADA may amend its requirements at any time with reasonable advance notice and thus has control over its expenses for aviation weather services.

MSC services to NAV CANADA under the 2001 agreement include the following:

- All aviation weather forecast services including TAFs, SIGMETs, graphical area forecasts, AIRMETs, and national SIGWX progs;
- The Montreal VAAC;
- All weather observation equipment at 235 aerodromes including equipment maintenance and observer inspection services;
- Observation data collection, processing, quality control and distribution;
- Delivery to air traffic facilities of other weather information including weather radar, satellite imagery, and WAFS products via a satellite broadcast system;
- An aviation weather web site;
- A license to receive lightning data derived from the Canadian Lightning Detection Network.

The total annual price for these services paid by NAV CANADA is approximately $18 million Canadian (not including equipment amortization costs) as compared to the government funding to the MSC of $172 million Canadian to undertake its public mandate. It is important to note that the $18 million Canadian paid by NAV CANADA to the MSC does not represent its total costs for aviation weather services. NAV

CANADA directly pays for all aviation weather observers at airports and operates a pre-flight aviation weather briefing service that is independent of MSC operations. Hence, that cost has to be added on.

NAV CANADA's costs for aviation weather services, as with all its costs, are built into its user fees. Air transporters pay en route, departure and landing fees that are based on the aircraft's gross weight and distance traveled. Non-commercial users pay an annual fee. There are no separate or supplementary fees charged for aviation weather services.

Canada differs from New Zealand in that instead of applying the ICAO guidelines directly as described in the opening paragraphs of Section 5.1, a different approach has been followed. This approach is based on the principle that there are two primary funding contributors to the national meteorological system and that each contributor requires full control over its own spending. NAV CANADA pays the full costs of aviation forecasts and the full costs of the surface weather observing program at airports. MSC pays the full costs of the core meteorological infrastructure (computing, meteorological research, etc.). The agreement between the two organizations includes an explicitly stated quid pro quo. NAV CANADA realizes a direct value from the government-funded infrastructure of the MSC. At the same time, MSC realizes a direct value from the NAV CANADA-funded surface weather observation network, which includes the synoptic weather observations at all major Canadian cities. In fact, the costs saved by the MSC through not having to fund this significant portion of the national surface weather network have been calculated to be approximately equivalent to the core costs that would have been attributed to aviation under the ICAO guidelines. The major risk with this approach for both organizations is that one party can take unilateral actions to reduce costs that have will have a negative impact on the other party. To date, this risk has not been a significant factor as both organizations have acted in good faith to consider the impacts of their decisions.

The change in relationship between the MSC and the air navigation service that came about was quite dramatic. Instead of a traditional interdepartmental working relationship, which could be collegial but also adversarial at times, a new, client-service provider paradigm quickly emerged. As a paying client, NAV CANADA demanded responsive service and demonstrated value for investment. A performance measurement system was put in place that included performance penalties and bonuses. Aviation meteorology, which had diminished in importance within the MSC over the years as priorities shifted to environmental and climate changes issues, was once again a key concern for senior departmental managers. Changes were made in operational procedures to meet the requirements of the agreement with NAV CANADA. These included nationally standardizing many procedures where significant regional variability in approach had evolved, as well as the introduction of new quality monitoring procedures. The outcome had very positive consequences for the MSC operational programs overall. In general, the impact of the new relationship, with a well-identified paying client, incited a number of constructive changes in the operation of the MSC.

One area that did not benefit from this new relationship was meteorological research and development. NAV CANADA has shown only limited interest in funding development.

Such action is undertaken on a case-by-case basis where a clear business case can be made with cost saving resulting from the investment. MSC remains the organization with the greatest scientific capacity to carry out aviation weather R&D, but there has been a reluctance to invest public funds on an area that is intended to be user-pay and is not directly within the department's legislated mandate.

Finally, the relationship of the military to MSC in Canada is of interest. The Department of National Defense uses meteorologists from the MSC to provide military weather forecasting services. The Department of Defense benefits from all of the civilian air navigation system forecasting products and services, but contributes no funding for the effort. (Private correspondence; John Foottit, Manager, Aviation Weather Services NAV CANADA).

3.2.3 Aeronautical Meteorological Services provided by the United States of America

The Aviation Weather Service of the United States of American (USA) represents yet another model providing aeronautical meteorological services. In this model, a government agency is reimbursed for services from the United States Airport and Airways Trust Fund. The Aviation Weather Service of the National Weather Service (NWS) is an integral part of the basic weather service system. It is difficult to separate it from the basic system, particularly in those aspects concerning surface and upper air observations. The Meteorological Authority for the USA to the ICAO is the Federal Aviation Administration (FAA). Up until the mid-1980s, the FAA provided the NWS a line item of funding using the Trust Fund to reimburse the NWS for providing aviation services. In the mid-1980s, the U.S. Congress made the line item a permanent part of the NWS budget with the proviso that when the FAA needed new services, those services would receive additional funding from the FAA. However, the operational budget of the NWS for aviation weather has been level-funded for the better part of three decades in spite of increased services provided by the NWS.

The FAA meets their ICAO requirements through the provision of aviation services by the National Weather Service. A memorandum of Agreement dating back to 1965 between the FAA and the NWS outlines the responsibilities of both agencies. The memorandum was updated in 1977 and again in 2003. The agreement gives pilot weather-briefing authority to the FAA, and gives authority for forecasts to the National Weather Service. The FAA has maintained 58 Flight Service Stations across the USA to provide the aviation briefings and flight plan filing. On February 1, 2005, the FAA awarded a private sector contract to Lockheed Martin to operate 20 Automated Flight Service stations across the United States for a ten-year period. The other 38 offices will be closed. This begins the process of bringing the United States closer to the Canadian model.

In 1982, the National Weather Service centralized the production of the Area Forecasts and AIRMETs and the SIGMET program at the National Severe Storms Forecast Center in Kansas City. This centralized facility was called the National Aviation Weather Advisory Unit (NAWAU). Eventually, all ICAO-required services provided by the USA, with the exception of areas in Hawaii and Alaska, were moved to Kansas City and the Aviation Weather Center (AWC) was established. When the WAFS centers were made permanent in Washington D.C. and London, the AWC was given the responsibility to produce the SIG WX charts for the Washington D.C. WAFC.

A large part of the aeronautical meteorological services provided by the U. S. federal government are free. There is no cost recovery. However, FAA provided services through Flight Service Stations (FSSs) are paid for from the Airport and Airways Trust Fund. TAFs are provided by the Weather Forecast Offices of the National Weather Service (NWS). The Aviation Weather Center provides aviation-specific weather products on its Aviation Digital Data Service (ADDS) delivered over the Internet (see the URL: adds.aviationweather.noaa.gov). Many of the forecasts there represent fully automated products generated by high-resolution mesoscale weather forecast models.

A number of large airlines have their own meteorological departments to provide specialized aviation forecasts for their use. There are a number of private providers in the U.S. who give specialized weather service to the business and general aviation segment. The U.S. also has meteorologists in all the Air Route Traffic Control Centers. Funding for the personnel and infrastructure are provided by the FAA under a separate contract to the NWS. Again, the funding for this program is provided through the Airport and Airways Trust Fund. The employees at these centers are NWS employees.

Quality control of weather products is an important part of the overall effort. Under sponsorship of the FAA, a laboratory of the National Oceanographic and Atmospheric Administration is responsible for the software that provides verification and quality control of AWC and NWS aviation products.

The military uses AWC products for en route weather. However, TAFs for United States Air Force bases and United States Naval Air Stations are produced by the respective military services. There is a cooperative backup agreement between the United States Air Force and the AWC. When the AWC has a failure and cannot produce products, the United States Air Forced produces en route products over the contiguous 48 states of the United States.

3.2.4 Aeronautical Meteorological Services provided in the European Union (EU)

At the current time, most European countries provide aeronautical meteorological services on a fee basis in the individual countries. Finland is an example of a country where the delivery of meteorological services is expected to make a profit. In Finland, there are two centers for aviation services. Both centers provide the domestic and military aviation services. In France, Meteo France has a large aviation section that sells its services worldwide.

Beginning in 2005, a new program named Single European Sky has taken effect. This program applies to all EU members. It separates the service provider from the service regulator. Each nation state will be able to designate an exclusive service provider. An authorized provider will be able to operate in another nation state if that nation state has not designated an exclusive service provider. It appears that this program will be very similar to the New Zealand concept.

3.2.5 Aeronautical Meteorological Services provided by Taiwan

In Taiwan there are two separate national weather agencies, both operated by the central government. The Central Weather Bureau (CWB) provides general meteorological and hydrological services to the country, including the operation of a national Doppler weather radar network (four radars). Aviation weather services are handled within the country's Civil Aeronautics Administration (CAA), under their Air Navigation and Weather Services unit.

Aviation weather services to the Taiwan FIR are centralized at the Taipei Aeronautical Meteorological Center (TAMC). In addition, the CAA maintains weather observing offices at ten airports throughout the country, including Taiwan's main international airport at Chiang Kai Shek (CKS). The CKS airport weather office is a large facility, with its own Doppler weather radar. CKS and Sungshan (the downtown Taipei domestic airport) have installed Low Level Windshear Alert System (LLWAS) warning systems to detect hazardous windshear events.

These two separate weather services managed by CAA and CWB share their observational data, but have historically operated as totally separate organizations. Recently, however, CAA upgraded their aviation weather services through the development of an Advanced Operational Aviation Weather System (AOAWS) that provided a modern, computer-based data integration and forecast preparation environment. As part of the AOAWS initiative, CAA and CWB agreed to jointly operate a numerical weather prediction center running a high-resolution, nested-grid, mesoscale model. This system provides automated aviation weather products to a network of workstations distributed in airports and weather offices around the country. Pilots are able to get self-briefings at conveniently located workstations at airports, or over the Internet. These automated weather products and Internet delivery, developed under contract with a U.S. organization, are similar to the ADDS service provide by the Aviation Weather Center of the U.S. National Weather Service.

4 Recommendation for Establishing a Modernized Aeronautical Meteorological System in Colombia

In Working Paper Number 1 the EarthSat consultants reviewed in detail the operational requirements for an aeronautical weather service in Colombia based on both international and regional agreements. Working Paper Number 1 also reviewed in detail the requirements levied by a broad spectrum of end-users of aviation weather information. The operational requirements were summarized again in Section 2 of this document (Working Paper Number 3). In the previous section, examples were presented showing how these requirements have been interpreted into the provision of aeronautical meteorological services by a number of countries.

In most of the models that were cited in Section 3, nation states have either centralized their weather service or are in the process of doing so. Consider again the Canadian model. In the first few years of the NAV CANADA contract there were eight offices delivering aeronautical aviation services. That has now been downsized to two offices. Recognizing the huge number of TAFs and the large and diverse geographic area that has to be "met watched," the Canadians have used a mix of technology, training and communications to accomplish the task. They have reduced the number of flight service stations by using briefing kiosks and upgrading the technology in the stations. Such an endeavor is also possible in Colombia. New Zealand, as another example, has one central office.

Based on a consideration of the formal requirements, the end-user statements of requirements, and the range of examples found in other countries, the consultants have focused on a range of solutions that has a single common element: the creation of a Colombian Aeronautical Meteorological Center (CAMC). This single facility, located in Bogotá, would perform all the high-level warning and forecasting activities expected of a modern aviation weather system, including widespread electronic dissemination of information in graphical format to users in all parts of the country.

There are a number of options in how this concept could be implemented. These options principally involve the following questions:

- Where is the Center located administratively in the government structure of Colombia?
    - Presumably it would be in AeroCivil, as the cognizant agency in Colombia
- Who would staff the Center? For example:
    - AeroCivil personnel, with some forecasters transferred from IDEAM
    - Personnel from different agencies (e.g., staff loaned from IDEAM or the Colombian Air Force)
    - Private contractors
    - Some combination of the above
- How would the costs of running the Center be supported? For example:

- Government budget line item
- User fees

In Section 5 we consider the options for governance, staffing, and funding based on several possible scenarios. But first it is helpful to understand the intended functions of the CAMC in relation to the requirements for aviation weather information.

4.1 Concept of a New Colombian Aeronautical Meteorological Center (CAMC)

The creation of a dedicated aeronautical meteorological center would have four objectives:

- To provide improved *aeronautical weather information*
- To enhance the ability of *aviation decision makers* to use the information
- To utilize *research and computational assets* related to aeronautical weather that have been developed around the globe
- To facilitate improvements by forging the required *institutiona*l *arrangements*

This plan involves the development of an infrastructure capable of providing modern aeronautical meteorological services to all the users of the Colombia airspace system, including traffic controllers, pilots, and airlines. The concept calls for a centralized Colombian Aeronautical Meteorological Center. While located in Bogotá, it would effectively serve all parts of the country by disseminating accurate weather information over the Web in both graphical and alphanumeric form, and by providing pilot flight briefing services and services to air traffic controllers over the telephone and radio.

The creation of the fully implemented CAMC would involve a process to be fully realized over a period of years. The Center would have a Director, Deputy and appropriate personnel to operate the national program, and would constitute a new formal organizational unit. It would build on the current Bogotá Meteorological Watch Office and add to the expertise there. The provision of aviation weather information would be expanded to include TAFs for all controlled airports in Colombia as well as appropriate SIGMETs and AIRMETs. The CAMC would have five functions:

- Issue all warnings of hazards over the Colombian air space
- Issue all TAFs for Colombia
- Ensure the Area Control Centers have enough meteorological information to direct traffic in a safe and efficient manner, including human briefings as necessary
- Produce high-resolution, accurate weather forecasts through the operation of a mesoscale numerical model
- Deliver current and forecast aviation weather information, including automatic graphical products, over a communication network to the broad community of end users, including airlines, pilots, and air traffic controllers.

The CAMC would have sufficient staff to carry out the aforementioned operations. Details on staffing options are deferred until Section 5, but could include staff from a number of sources including: AeroCivil, IDEAM, the Colombian Air Force, and private contractors.

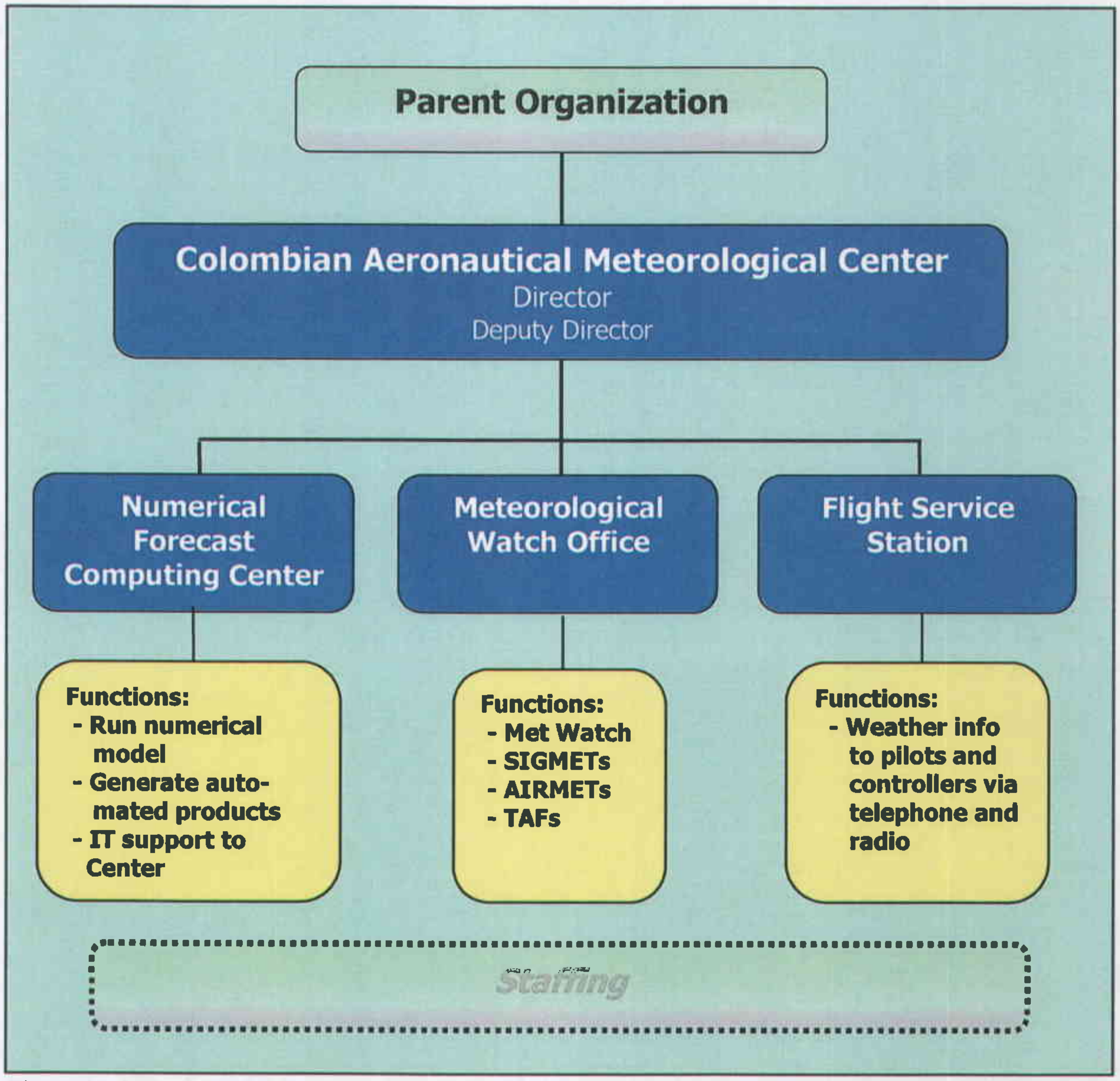

Figure 4.1 Organizational structure of the Colombian Aeronautical Meteorological Center (CAMC). Note that the parent organization to which the CAMC reports is proposed to be AeroCivil. A discussion of the governance and staffing options are considered later in Section 5.

In this plan, the observations at all controlled airports would become automated and available 24 hours a day. The Colombian Aeronautical Meteorological Center would provide all the ICAO required products, support the air traffic controllers at the Bogotá and Barranquilla en route centers as well as controllers at the nine or so approach control facilities, produce TAFs for all mandated airports and provide additional services as might be required.

4.2 Functions Supporting the Delivery of Meteorological Services in Colombia

The organization structure for a fully implemented Service is illustrated in Figure 4.1. We now consider the various parts of the proposed Center in more detail.

4.2.1 CAMC Meteorological Watch Office (MWO)

The name "Meteorological Watch Office" is the ICAO term for the office that provides the key aviation services in a country. This office in comprised of trained meteorologists who monitor the weather for the full day and night, and who are responsible for disseminating information as necessary. This information includes SIGMETs for such things as turbulence, icing, and volcanic ash. It also includes AIRMETs or GAMETs (lower flight level information, often for general aviation use). While these are not required under the CAR/SAM regional standards, they should nevertheless be considered an important element for a modern aviation weather system.

In the concept proposed here, this unit would also be responsible for providing TAFs for all controlled airports in the country.

In considering the staffing requirements, it is assumed here that the CAMC would be in operation 24 hours per day, 7 days per week. In general five personnel are required to support each full-time position under a 24/7 model (assuming 8-hr work days, and 5 work days per week). The personnel requirements for the MWO are then estimated as follows:

- One Supervisor who reports to the Director of the CAMC
- Five Category 1 lead forecasters who would handle the ICAO program for SIGMETs, AIRMETs and Met Watch, and supervise the TAF production
- Fifteen Category 2 and 3 meteorological technicians who would support the lead forecaster
- Two maintenance employees
- One support staff

The environment at the CAMC central facility is indicated schematically in Fig. 4.2. The environment assumes high-speed broadband connection between the CAMC and all controlled airports in Colombia.

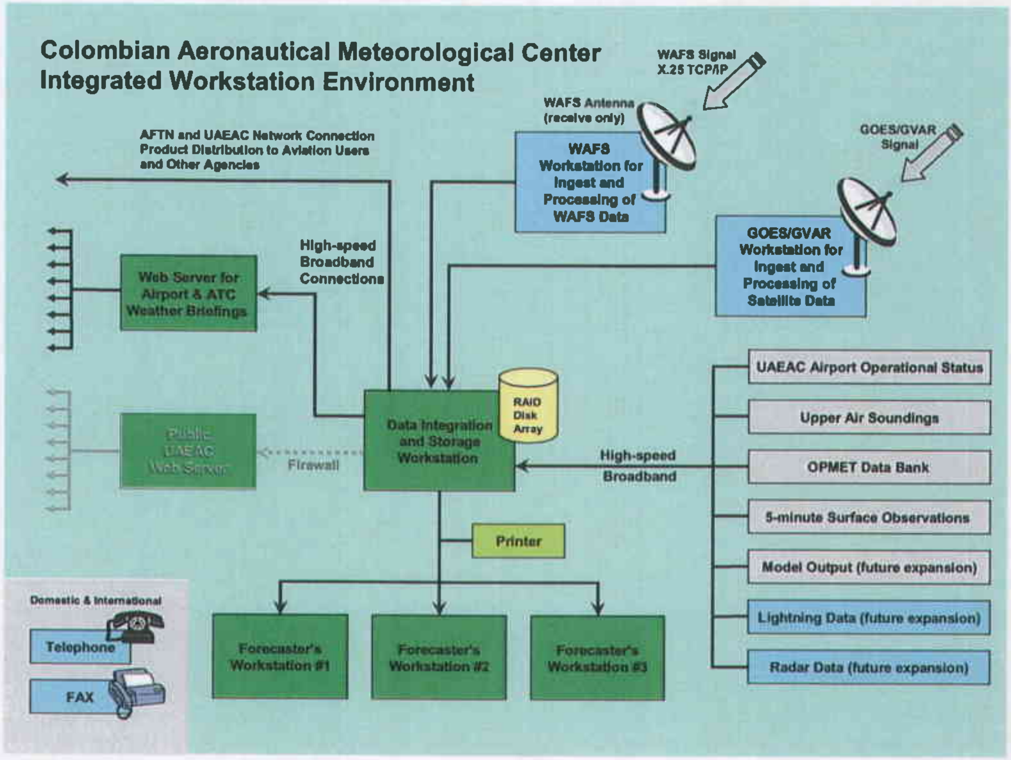

Figure 4.2 Schematic diagram of a possible work environment for the Colombian Aeronautical Meteorological Center.

4.2.2 Flight Service Station

In many countries the ICAO requirement for providing weather briefing services to pilots (both commercial and general aviation) is met by Flight Service Stations (FSS). These are often located at a number of regional centers. However, as noted earlier, there is an increasing trend toward centralizing this function, since widespread distribution of graphical weather products over the Web is now efficient and economical. Such a centralized concept is proposed for Colombia.

The Flight Service Station would be part of the CAMC, and weather briefers there would work along side the meteorologists of the MWO. Personnel in the FSS would be responsible for flight briefing and filing flight plans. As noted, it is assumed that a briefing kiosk (a workstation) will be located in each airport, and the primary role of the briefer will be to answer questions and provide additional factual meteorological information, as requested, concerning the flight plans. Pilots flying out of Bogotá could access this service by talking face-to-face with meteorological briefers. Pilots at other airports would access this service over the telephone. In order for users to get the full benefit from the FSS system, Colombia will need to add a radio-link capability so that pilots in-flight can also access important meteorological information.

It is assumed that flight folder information required to satisfy ICAO requirements for international flights would also be automated, but the briefer could provide additional information as requested. The briefer would monitor takeoff and landing conditions at each airport in their region and notify the MWO if TAFs are not consistent with the on-going observations.

Another important function of the FSS will be to provide information to the personnel at the various air traffic control (ATC) facilities in Colombia (both the controllers for en route traffic, and for approach control to airports). Controllers need to be aware of all weather factors that can influence aviation safety and efficiency. Forecasters, in turn, need information from pilot reports of weather impacting the air space, and the controllers are the conduit for this information. The AIREPs, in combination with other information, are an important factor in evaluating whether the MWO will issue a SIGMET or AIRMET.

In the proposed system, all the ATC facilities would be provided with weather information systems (workstations) equivalent to those proposed for the self-briefing kiosks at airports. FSS personnel would be available by telephone to discuss developing weather situations with flight controllers and answer questions, as with pilots. The FSS staff would ensure that verbal reports of hazardous weather conditions were encoded into formal AIREPs.

The Flight Service Stations would have a personnel structure as follows:

- One Supervisor who reports to the Director of the CAMC, and who works hand-in-hand with the MWO supervisor
- Five Met Techs, WMO Category 2 or 3, initially (one full-time equivalent)
- As the utility of this service grows and it becomes heavily used by both pilots and controllers, the number of staff needed is expected to grow by a factor of 3 to 5.

4.2.3 Numerical Forecast Computing Center

One feature that is central to the concept proposed for modernization of the Colombian aeronautical weather services is the use of a regional weather forecasting model tuned to the Colombian environment and delivering automated products over the Internet. This follows closely the examples in the U.S. and Taiwan, and is considered the model of where aviation weather services should be headed. The regional models, which are nested with global forecast model output produced by the international centers, produce much more accurate and detailed information, and are in a position to ingest important local data sources. Such models are essential to implementing the algorithms that produce automated products such as turbulence warnings.

Establishing, configuring, and upgrading a mesoscale weather prediction model is a complex process. It is assumed here that this part of the effort would be contracted out to a responsible party. Thus, the staffing listed in the following estimate is fairly lean in comparison with typical numerical modeling centers. Most of the computational work would be routine operations, trouble shooting, and data ingest problems, and model version updating rather than development work. The computational domain for the mesoscale model would be expected to cover Central America and the northern part of South America along with adjacent oceanic regions.

Supporting the computing center and running the numerical weather forecast models would require a minimum personnel structure estimated as follows:

- One Supervisor who reports to the Director of the CAMC
- Five computer operators
- Three software engineers
- Two-to-four maintenance employees, who would also provide general Information Technology support to the CAMC
- One support staff

4.3 Other Characteristics of the Center

4.3.1 Physical environment of the Center

A building to house the CAMC facility should be able to accommodate some 50-60 personnel, though many of the personnel would be shift workers due to the round-the-clock nature of the work. The facility should be equipped with emergency and conditioned power, and should support computer operations and wideband connectivity throughout. A conference room should be included that would be available for staff meetings and seminars. A lighted parking area to accommodate employee and visitor automobiles should be available. The exterior of the building and the parking area should be monitored with video surveillance and alarm systems.

A satellite antenna farm should be located adjacent to the facility and provided with emergency power backup. A radio frequency interference study should be done to ensure no or minimal interference among nearby systems. The antenna farm should accommodate the GOES Satellite Receiving Antenna, WAFS receiving and transmitting antenna, and modernized communication antennas. The operational area set aside for forecasting functions should be designed to maximize and facilitate coordination among the various forecaster workstations.

4.3.2 Focus on the end user

The development of such a center has the ability to focus on the user. These include pilots, dispatchers, terminal operators, traffic management and flight planners, as well as air traffic controllers. Dr. John McCarthy, an international aviation expert, has said that "*any effort to improve weather services has to take into consideration that it's not the weather that's important but what we do with the weather (information)*." Understanding the end-users' requirements and finding the information path to those customers are of critical importance. Modern information technology techniques and the Internet have changed the paradigm. A dedicated high-speed and broadband intranet for aeronautical weather services is encouraged and is technically feasible.

The Center should focus not only on providing aviation weather information, but also on continuously evaluating the accuracy of its products, and seeking an on-going dialogue, perhaps through a standing committee, with aviation end users of weather information. Only with these two elements can the Center guarantee that its products are relevant.

4.3.3 Focus on Automation

The phased movement to a CAMC concept can only be successful if that concept embraces automation. The surge in technology can benefit the acquisition and dissemination of aeronautical weather information. The role of forecasters will be different, and it requires that they be equipped with the decision tools to increase productivity (semi-automation) rather than simply encumber their work with technology. There are workstations available now that can greatly aid the modernization of the delivery of aeronautical weather services. Modification of existing software can be done in a straightforward manner at a reasonable cost. The U.S. and Taiwan models for the creation and broad delivery of automated aviation-specific weather forecasts and warnings over the Internet should be embraced.

5 Options for the Development of a Colombian Aeronautical Meteorological Center

Following the discussion in Working Paper 2 and the recommendations in the preceding section, options for a development plan are now considered. That development plan needs to consider the end state of a fully mature Center, as well as a transition plan that moves forward from the current system. It is noted here that in all options considered, a more comprehensive education and training program is required to develop and maintain a modernized aviation weather service. This topic is so important it is considered separately in Section 6.

The development plan assumes that Colombia has 47 controlled airports and will eventually have continuous automated 24-hr observations from each. A listing of those airports can be found in Working Paper 1. This plan assumes that a comprehensive AWOS Replacement program begins in Calendar year 2006 and continues through 2015.

The EarthSat Team understands that there are currently about 118 employees (updated to reflect 2005 data) engaged in the delivery of aeronautical meteorological services in Colombia. That mix is made up of 99 full-time Met employees from IDEAM, and about 19 full-time equivalent employees from AeroCivil. In the proposed transition, no employee would be displaced from employment in the first year. The transition plan would initially emphasize the use of staff to provide weather briefings based on information obtained in TAFs, model guidance, and current weather observations. A screening process should be designed to identify those personnel best suited to generate TAFs. A training and education plan will accompany the proposed revamping of the organization.

In the preceding Section, the basic structure and function of the CAMC was outlined. In describing a complete aviation weather system, one also needs to discuss the basic observations that are the building blocks of all weather products, as well as the operations and maintenance of the observing equipment. This general concept is illustrated in Figure 5.1. The observing equipment itself was the subject of detailed discussion in Working Paper Number 2. In the following we consider various options for the governance and staffing of the center, the staffing or non-staffing of the weather observation function and of the operations and maintenance function, and the source of financial support for the endeavor.

5.1 Maintain the Status Quo

The first option considered the current arrangement in Colombia involving the inter-agency agreement between IDEAM and AeroCivil. One possibility to consider would be to build a system that continued this arrangement, possibly with modifications to mitigate current deficiencies. This model somewhat fits the United States model where AeroCivil (FAA in the U.S.) and IDEAM (NWS in the U.S.) each provide some services.

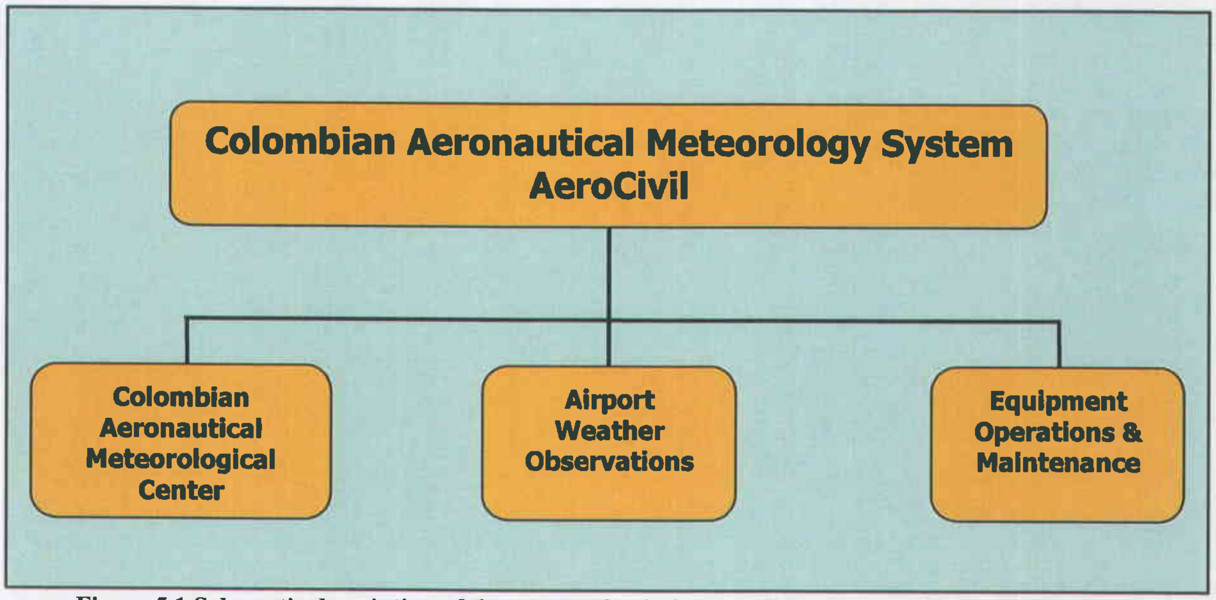

Figure 5.1 Schematic description of the proposed aviation weather system for Colombia.

As shown above, the CAMC, airport staff necessary to produce METARs, and the staff to operate and maintain the observing systems represent the three main organization elements of the total system.

As illustrated in Section 3, an agreement regarding such services should include:

- Deliverables
- Frequency and timing of information
- Standards to follow
- Performance measures
- Payment schedules
- Dispute resolution procedures.

The current agreement falls short in meeting the above recommendations. Continued reliance on the current agreement is not recommended and a new arrangement should be developed. Moreover, the agreement should ensure that the services are provided to the degree and in a manner consistent with the international commitments made by the Colombia. It should be noted that some of the deficiencies identified in Working Papers 1 and 2 were listed by international aviation organizations in past years. This situation serves to minimize the credibility of the aeronautical meteorological data provided by Colombia to the world community.

This option assumes all 118 employees initially engaged in providing Aeronautical Meteorological Services in Colombia continue in their present jobs. As automation of the METARs takes place, there would be reduction in numbers of employees engaged in providing aeronautical meteorological services. The reduction would depend on the numbers of airports that were fully automated.

5.2 Most Aeronautical Meteorological Services Provided by IDEAM; Surface Observations Provided by AeroCivil

The second option is to move to IDEAM the required provision of the higher level meteorological services to satisfy operational needs. In this option the provision of forecasting services, and hence the staffing of the CAMC, would be assigned to IDEAM, while all airport surface observing equipment, maintenance of this equipment, personnel, siting, and the actual observations would remain with AeroCivil. All other observations (radiosondes, and surface observations at other sites) would be assigned to IDEAM. If this option were adopted, then it would be most natural for the CAMC to report administratively to IDEAM.

Depending on how it is structured, this model could either follow the Canadian model or the U.S. model. In the Canadian model, all airport surface observations would stay with AeroCivil and all other services would be provided by IDEAM. Model forecasts, upper air observations, TAFs, SIGMETs, AIRMETs, etc, would all be done by IDEAM. In the Canadian model, AeroCivil would negotiate a contract with IDEAM for these services. The funding would either come from government sources or from cost recovery. Following the U.S. model, AeroCivil would retain the surface observation and flight service station program and would determine what services IDEAM would perform. AeroCivil would seek funding from either government sources or cost recovery to pay IDEAM for the services. The location of the CAMC in IDEAM would be similar to the U.S. example, where the Aviation Weather Center is part of the U.S. National Weather Service.

Working Paper 1 outlined the deficiencies in the current system. Aviation meteorology, which is currently diminished in importance within IDEAM, would have to become a key concern for senior departmental managers within IDEAM, and a true aviation section would have to be created. As in the case of New Zealand, AeroCivil would have to write an equivalent Rule 174 that would spell out to IDEAM certain quality standards to be maintained. These standards would include personnel and training, sites, facilities, communications, records, manuals, and quality assurance procedures. AeroCivil should provide the funding, which would either be from government sources or cost recovery, and conduct regular audits to ensure all mandated services were being carried out.

Reiterating, in this option, AeroCivil would have the responsibility for providing and maintaining all the basic airport observing systems, including meteorological observations and measurements. A clear division of responsibility would need to be defined so as to simplify the full integration of the meteorological systems into the airport infrastructure, communication links, and operational support. AeroCivil would also be directly responsible for the meteorological observers who work with the airport observing systems. If implemented, this would mean transferring a considerable number of MET observers from IDEAM to AeroCivil, at least during the transition phase. The longer term plan calls for automating most of this function, and fewer observers will then be required. Non-aviation meteorological responsibilities, including general synoptic, climatological, and hydrological observations, reporting, and forecasts would, of course, remain the sole responsibility of IDEAM.

This option begins with the current 118 employees. In the course of the transition, there would be 31 IDEAM employees and 16 AeroCivil employees to staff the CAMC. The 16 AeroCivil employees would operate the Bogota Flight Service Station within the CAMC. An additional 35 AeroCivil employees would be used to staff seven regional flight service stations if Colombia decides to implement that aspect of the proposal. There would be a total number of 82 employees at the end of the 10-year period.

5.3 Contract with a Private Vendor for Aeronautical Meteorological Services as a Transition to AeroCivil Assuming Responsibility

In a fully exploited version of this third option, AeroCivil would contract the operation of the aeronautical meteorological service program for a period of approximately five years. During this period, the system would be similar to the New Zealand or European model. The contract could be with a private entity based in Colombia or elsewhere. Such an option would also require that the current agreement between AeroCivil and IDEAM be renegotiated or possibly terminated in its entirety. This period would be considered a transition. During this transition the private contractor would have the responsibility to hire and train local personnel. The goal would be that at the end of the transition period all the aviation weather services would be turned over to AeroCivil for operation by Colombian staff.

This option raises significant questions about equipment ownership and the maintenance of said equipment. Would UAEAC own all the equipment and maintain it, or would the contractor? The contract could be written in such a way that the equipment and maintenance are the sole responsibility of UAEAC and the contractor would only be responsible for personnel, services, and training. Conversely, the contractor could follow an AeroCivil program that allows the contractor to purchase the equipment under the supervision of AeroCivil staff. AeroCivil would maintain quality control standards as part of the contract.

Another important issue is the training. There are examples around the globe of many contracts to operate the aviation weather services programs of individual countries. In most of the scenarios examined by the EarthSat Team, there was no provision of training in the contract for the delivery of weather services. Another possible scenario would be for the provision of weather services by a contractor, and for training of Colombian personnel to remain under the direction of AeroCivil with the idea that at the end of the five-year contract, trained Colombian personnel were ready to assume the operation of a Colombian aviation weather service. Such a scenario would give the Colombian government five years to provide training for personnel, establish an infrastructure, and spin-up the new aviation weather service.

Under this option, the equipment necessary to operate the program could be owned by AeroCivil, which would also be responsible for its maintenance. An infrastructure would have to be identified that Colombia would use for the provision of weather services during the second five-year period of a ten-year plan. Personnel requirements would be identified to match the infrastructure, and those personnel trained to be ready to assume control of the program at the end of the first five-year period. Another alternative is for the contractor to be responsible for purchasing and maintaining the equipment for the five-year term. During this period, the Contractor would also train Colombians to maintain the systems. This would help ensure that the Contractor did not unfairly blame AeroCivil if the equipment malfunctioned and the provision of services was degraded. At the end of the five-year term, UAEAC would purchase the equipment from the Contractor at a discounted price negotiated as part of the contract.

One problem that might be noted with this option is the lack of a suitable commercial aviation weather services provider in Colombia. Thus, a non-local contractor would have to be retained.

As another important element, a comparison of the cost and benefit of contracting the service versus the cost of in-house performance needs to be performed as part of the decision process. When conducting cost comparisons, agencies must ensure that all costs are considered, and that these costs are realistic and fair. Any option that is adopted should meet the criteria of a Most Efficient Organization (MEO). The MEO refers to the Government of Colombia's in-house organization and its cost and ability to perform a commercial activity. It may include a mix of government employees and contract support and is the basis for all Government costs entered on a Cost Comparison Form. The MEO is the product of the Management Plan (in this case the five-year plan to contract aeronautical meteorological services), and is based upon a pre-defined Performance Work Statement (PWS). A Performance Work Statement identifies the technical, functional, and performance characteristics of the work to be performed; specifies essential functions to be conducted; and determines performance factors, including the location of the work, the units of work, the quantity of work units, and the quality and timeliness of the work units. It serves as the scope of work and is the basis for all costs entered on a Cost Comparison Form.

In the case of the above option, the cost to the Colombian government of utilizing a PWS based on a non-government contract appears to be more costly than upgrading the internal organization to meet the requirements. A mix of contractors and government employees would also be costly. However, in the final analysis, a detailed study would have to be performed to determine the exact costs of the options and identify the MEO.

In this option, a contractor would operate all of the current airport sites that manually produce METARs, provide briefings, file flight plans, and would operate the Bogota MWO. At each site the contractor would make use of rehired IDEAM or AeroCivil employees, or bring in their own employees. In any event, 82 employees need to be selected for training and employment in the new Colombian Aeronautical Meteorological Service. This is in addition to the employees engaged in the ongoing aeronautical weather services program. As you select and train employees for the new Colombian Aeronautical Meteorological Service, you can assume that the initial total of 118 will shrink due to automation of METARs. However, there may be an overage until a sufficient number of METARS could be generated from the establishment of automated weather observing systems.

5.4 Move the entire Aeronautical Meteorological Program to AeroCivil

In this fourth option, all of the aeronautical meteorological services and support would be assumed by AeroCivil. This would include staff transfers as well as equipment and maintenance transfer. "Met Gardens" as a source of aviation information would be replaced in a phased program, and there would be new observational platforms at the approach end of the primary runway at the aerodromes. The radiosonde program would remain with IDEAM, as Colombia's designated WMO representative, and the Colombian Air Force. Enhanced workstations with a new infrastructure would provide improved service over what is currently available. An enhanced training program would be provided for the AeroCivil personnel so that they could meet WMO and ICAO standards developed for provision of services. AeroCivil would fund a Colombian weather prediction model designed to support aviation within the Colombian FIRS or require a more robust model to be run at IDEAM for forecast of specific aviation variables. A quality control program would be developed to provide feedback to officials charged with operating such a program. This ensures that the value of the program would be used to support continuous adequate funding for maintenance and phased improvements.

Such an option has a number of advantages. Among these are:

- UAEAC is the aviation MET authority for Colombia in the eyes of the ICAO and CAR/SAM organizations. As the MET authority, UAEAC has the strong motivation to:
  - Meet all requirements of a modern aeronautical meteorological service
  - Develop a source of funding adequate to this purpose.
- Planning, designing, and implementing a new system with phased improvements is an easier task when managed by a single entity.
- As suggested in Working Paper 2, airport meteorological systems and supporting infrastructure should be provided, maintained, and operated under the control of AeroCivil staff. This approach facilitates the integration of these systems and operations with other airport services and communication links.
- A new organization within UAEAC with appropriate expertise can provide a vital link to the customers within Colombia (airlines, ATS, airport operators, private pilots, etc.) that are demanding improved services.
- Verification and quality control programs would be organized within the new organization for the sole purpose of improving the overall integrity of the aeronautical meteorological program.

Disadvantages or uncertainties associated with such a program also need to be considered:

- Creation of a separate meteorological service within Colombia may ultimately cost more in terms of duplication of various aspects of the requirements. The duplication would occur unless there were tight agreements that cite specific observations, modeling resources, and numerical guidance to be shared among all the agencies performing meteorological forecasts.
- AeroCivil does not currently have the meteorological expertise. The forecasting staff would have to be transitioned from IDEAM to AeroCivil.

5.5 Recommendation

Based on the considerations above, it is recommended that a solution be sought in terms of the option discussed in Section 5.4, to wit: concentrating the provision of aeronautical weather services within AeroCivil. However, this implies that mechanisms have to be identified to mitigate the disadvantages noted above.

A significant problem relates to the lack of qualified personnel within AeroCivil to perform the forecast functions needed for the CAMC. The first step in the process will be to create a Colombian Aeronautical Meteorological Service (CAMS) with a director that reports to the Director of Operations of AeroCivil. Following this, the Director of CAMS can immediately formulate a plan to address the problems associated with the lack of qualified personnel. The EarthSat Team recommends that AeroCivil take advantage of outside "mentors" or visiting "experts" to help them get started. The transition will have to be gradual and have a strong initial emphasis on training and recruiting. This situation has to be addressed immediately if modernization is to take place within a reasonable time frame. Several solutions are possible.

1. *The CAMC is staffed only with AeroCivil employees.* This is the **primary recommendation**. In this case a government decision would have to be taken in which forecasters from IDEAM would be moved administratively to become employees of AeroCivil in order to fulfill the functions of the CAMC. There should be "competition-based selection" of IDEAM's "best and brightest" staff members with the understanding that those selected will have better training opportunities, higher grade classifications, and better opportunities for future promotions. This option would eliminate the need for an inter-agency agreement between the two agencies, and the difficulties that have arisen in their attempting to work together in the past.
2. *The CAMC is staffed with employees of AeroCivil and IDEAM.* This concept of shared responsibility has not worked in the past and the EarthSat Team believes there is little hope for it to work in the future. However, it is an option. In this multi-agency concept, staff from IDEAM could rotate into a position at the CAMC, where they could learn new skills as well as train AeroCivil staff. After a period of time, they could return to their home institution or alternatively, they could stay with AeroCivil. Given the multi-agency nature of the concept, IDEAM could forge links with AeroCivil and find ways to take advantage of the advanced

weather forecasts being produced by the numerical forecast model. This concept could be extended to include personnel from the Colombian Air Force, as well as scientific staff from the local academic community with relevant research or numerical modeling interests. Developing this option would involve negotiating new inter-administrative agreements.

3. *The CAMC is staffed with contract employees*. This solution is the least favored of the three and a very careful financial analysis should be undertaken before this solution is tried. Contract employees could be used for the entire function of the Center, or this option could be considered a variation of Option 2, with contractors thrown into the mix described for Option 2.

Regardless of the recommendation option that is implemented, the EarthSat Team recommends that Colombia consider bringing in outside meteorologists under a support or assistance contract, or grant to help with the transition. While the EarthSat Team recommends as a matter of principle, that Colombia try to develop their own expertise and build up a qualified staff of Colombian meteorologists, bringing in outside (i.e. non-Colombian) assistance or even outside leadership in upgrading their aviation weather program may well speed the transition. Therefore, the EarthSat Team recommends that staffing the CAMC, and the function of airport observers and the maintenance of equipment should be the responsibility of AeroCivil.

On the other hand, upper-air soundings are properly the responsibility of IDEAM per international agreements. These soundings are extremely important in the forecasting of aviation weather, and AeroCivil has a vested interest in ensuring that accurate upper-air soundings are taken with agreed-upon regularity. If soundings cannot be taken on an agreed-upon regularity, then AeroCivil should suggest that IDEAM delegate the operational support of the radiosonde program to AeroCivil (as discussed in Working Paper Number 2) or even undertake an agreement with IDEAM whereby the WMO responsibility is given to AeroCivil. This would include staff, equipment and supplies.

As indicated in Working Paper 2, the consultants recommend that airport observations move toward a fully automated system. However, no system to date has been successful in accomplishing that goal completely. The difficulty associated with automation comes at airports located in rapidly changing weather conditions or where thunderstorms are growing in an area that is yet unseen by the weather sensors. Such a scenario will warrant augmented report capability. This usually applies to airports with international service, but it can be important for any type of airport. Small aircraft are likely more vulnerable to severe weather than larger ones. It is envisioned that a part-time observer will be needed at the airport for the indefinite future to manually enter remarks or rapidly changing conditions into the METAR. It is possible that this function could eventually be a part-time responsibility of an AeroCivil employee primarily involved with other tasks (e.g., a tower controller trained for this function).

5.6 Funding

The consultants have been informed that AeroCivil intends to fund the modernization of the aviation weather services out of its on-going budget. Presumably this is true regardless of the decisions taken about staffing.

Another option that has been mentioned above is that of accessing the airport user and overflight fees collected by the government. The concept, along with ICAO and WMO guidance with respect to it, were discussed earlier in Section 3.2.

These options for funding will need to be reviewed by Colombian authorities in the light of the total costs required for the modernization.

It is worth noting that budget pressures are just as strong in Colombia as they are in other countries. Such pressures call for centralization and cooperation wherever possible. Any solution has to address the paradigm of end-to-end forecasting and a balance between service and scientific research that improves that service. There are numerous examples around the globe where the concentration of personnel in centralized locations provides a strong and efficient solution to the meteorological forecast problem. That is the solution recommended here, independent of the administrative connections maintained.

5.7 Proposed Implementation Schedule

Appendix B is a hypothetical schedule that outlines a sample plan that could be followed. Note that a decision regarding the movement or sharing of IDEAM employees is a key milestone for the whole plan. The schedule shown is meant to be suggestive only, and is not necessarily a firm proposal at this point.

The transition to the recommended Colombian Aeronautical Meteorological Center would take place over a number of years. Formally, the transition may be able to wait until the current 5-year IDEAM-UAEAC Inter-administrative Cooperative Framework expires in May, 2007. This would give the affected staff time to prepare for the new organizational structure and receive training appropriate for possible shifts to new meteorological positions while the new instrument systems start to arrive. It is expected that most of the staff currently providing aviation meteorological services in Colombia would be able to transition to similar or related jobs within the new organizational structure. Ultimately, however, there will be a net reduction in the number of MET staff. In particular, the shift to automatic observing systems will mean that there will eventually be a marked decrease in aviation weather observers. The more experienced observers would be able to train for higher-level forecasting positions, for positions as system maintenance technicians, or other positions within UAEAC or IDEAM. During the initial transition period, it may be appropriate to keep a MET-trained observer assigned to each airport equipped with automatic weather stations to monitor system performance, conduct preventive maintenance, and assist with pilot briefing activities. With the implementation of the recommended self-service weather briefing workstations, there would not be a need for full-time MET staff to be assigned to any Colombian airport except for the positions associated with the CAMC. This staffing transition, however, would take place over the ten years of the proposed master plan.

It is assumed that those maintenance personnel engaged in maintaining NAVAIDs would develop the expertise to maintain the automated weather stations. Maintenance of the workstations and the networking would be a task for the Operations and Maintenance unit shown in Figure 5.1.

6 Education and Training

6.1 General issues

Meteorological training is an essential part of any modernized Colombian Aeronautical Meteorological Service. The demands of a modern weather forecast and warning system require that Colombia develop additional qualified meteorologists, and that existing meteorological staff upgrade their skills with recurrent training. As discussed in Working Paper Number 1, it appears that recurrent training has been virtually non-existent in AeroCivil. A vigorous program needs to be undertaken to develop more WMO Category 1 aviation weather forecasters (there appears to be only one in all of AeroCivil). This topic is just as important for the meteorological technicians (WMO Category 2, 3, and 4), who need regular training to stay current as well as to advance to more qualified positions.

Note that in 2001, WMO instituted a new personnel classification system that simplified to some extent and redefined the four categories of meteorologist. The new guidelines, which are summarized in Appendix C, place new emphasis on job competencies, specialized knowledge and relevant education.

Everybody needs to receive training on a regular basis. Entry-level personnel need training to improve their skills and qualify for promotion. They also need training in the use, operation, and often the maintenance of new observing systems. Higher level staff needs more advanced training, often dedicated to in-depth understanding of new observing systems and advanced concepts. Staff should be cross-trained in a variety of specialty areas (e.g., satellite meteorology, radar meteorology, lightning and lightning detection systems, numerical weather prediction, interpretation of model output, and so on).

In order to perform at a high level of international standards, an operational meteorological organization needs to have local experts in areas such as satellite meteorology, who will pay special attention to the operational status of the associated receiving systems, be able to answer questions from other staff, and explain how to use the data sets to their best advantage. These staff will not necessarily be assigned to work full time with that particular data set, but should be given encouragement (and time) to develop specialist knowledge of the systems.

AeroCivil should also make a conscious effort to identify promising staff members to become internal "experts" in critical areas. These meteorologists and engineers should be encouraged to attend International Scientific Meetings and Congresses in their areas of specialty.

At the most advanced level, UAEAC should consider a program that would send outstanding staff members to international universities to pursue advanced degrees in meteorology (Masters of Science or Doctor of Philosophy).

6.2 Domestic Studies in Aeronautical Meteorology

The need for advanced training in aeronautical meteorology has clearly been recognized in the past by the Colombian authorities. For example, the inter-agency agreement between UAEAC and IDEAM (see Appendix A) specifically noted the lack of advanced education and training centers in Colombia, and was the motivation for promoting the Aeronautical Studies Center (CEA) where in-country training could take place. The CEA appears to be a useful start on aptitude building, but it is evident that much more needs to be done.

For the long-term health of meteorology in Colombia, it is important that the new CAMS work closely with local universities to ensure that Colombian students have an opportunity to receive university-level training without having to leave the country. Experienced IDEAM or UAEAC meteorologists should be encouraged to work with university professors to ensure that the course curriculum is appropriate for employment at IDEAM or UAEAC, or in the new inter-agency CAMS. On occasion, IDEAM or UAEAC meteorologists should be encouraged to teach university courses, either while on leave from their government position or as a part of their normal duties.

It would be valuable if IDEAM and UAEAC could support the university research program through the award of small research grants or work-study programs directed towards specific problems of aviation meteorology.

6.3 International Training

There are a number of ICAO and WMO training courses available, including many offered in South and Central America. A summary is given in Appendix D. These could be used more extensively for aptitude building in Colombia.

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Education and training are also available in the U.S. (this will usually require a good working knowledge of English). These include:

- FAA and NWS training programs. (e.g., FAA FSS School)
- COMET (some materials now becoming available in Spanish)

A wealth of training materials is also available for study. A selection of this material is listed in Appendix E.

6.4 Special Training Courses

In conjunction with equipment upgrades, UAEAC should organize and fund special training courses to be offered in Bogotá (or elsewhere in Colombia) with outside experts to address specific topics. The following are topics of interest in the current modernization plan:

- Thermodynamic diagrams and use of upper-air soundings.
- Forecasting low ceiling and visibility.
- Forecasting of convective weather.
- Mountain waves and clear air turbulence.
- In-flight icing.

These could be given as 1-week courses, with certificates and professional credit.

For example, as soon as the Colombian radiosonde system is upgraded and suitable analysis software (including thermodynamic diagrams) is available, there should be a major emphasis on making full use of these enhanced systems and tools.

6.5 Participation in International Meetings and Organizations

Senior staff, both managers and meteorologists, should continue to participate actively in international organizations such as ICAO and WMO. Staff should also be attending international meetings such as the Annual Meeting of the American Meteorological Society, which has an extensive exhibit program for vendors of meteorological systems of every kind. There is a regular series of scientific specialty meetings held in a variety of countries that are of direct importance to Colombia aviation meteorologists. In particular, there are regular meetings in the U.S. on "Aviation, Range, and Aerospace Meteorology" as well as many other specialties (see AMS web site, http://www.ametsoc.org/).

6.6 Guidelines for Training

In this report the consultants do not attempt to give an exact proposal for how much training should be undertaken, other than to note that the current level seems to be acutely deficient. In general, it is recommended that every member of the meteorological and engineering staff working in support of meteorological activities should receive at least two weeks of full-time training every two years.

While this guideline is thought to be suitable for the long term, there is a need for more training activity during the period of modernization and system upgrade.

All meteorological centers should maintain a library of meteorological reference texts and training materials that are available for self-study programs by staff. The WMO, for example, has an extensive set of meteorological publications of the sort that would be useful to have available (see Appendix E).

7 Summary

In this report on organization and management structure, the EarthSat Team has proposed several possibilities for modernization of the Colombian aviation weather system. After critical review and assessment, the central recommendation is that a Colombian Aeronautical Meteorological Center (CAMC) be put in place. It would involve a theme of centralization that embraces the most efficient use of resources available to support aviation services. This new entity, most likely organized under AeroCivil, could integrate relevant staff from AeroCivil, IDEAM, and perhaps the Colombian Air Force, and could provide valuable weather products back to each. Coupled with a master plan to provide system integration (best accomplished with a single systems-integration contractor), the CAMC will overcome known deficiencies in the provision of in-flight hazard services and aid Colombia in both meeting its obligations and becoming a leader in the CAR/SAM region.

A number of important decisions have to be made with respect to the recommendations noted here. Those decisions will then need to be translated into a development plan such as that suggested in Appendix B. The feasibility of the present recommendations in terms of funding, human resources, national will, and political realities will need to be carefully weighed. A conference that brings industry end-users together with government officials would be useful in further refining the relative priorities and timing of the various elements of the modernization such as: meteorological radar, a comprehensive network of automatic weather stations, a mesoscale weather model run locally and providing high resolution forecasts of significantly greater accuracy, a Flight Service Station function including a briefing and reference capability for air traffic controllers, an expanded TAF program, automated aviation weather products distributed over the Web, and a lightning detection network.

In this proposal, it is important to emphasize that improvements to aviation meteorological services will not only be of use to airlines, pilots, and dispatchers, but will also provide critical operational information for UAEAC's ATC personnel. The weather products could also provide value to other segments of the Colombian economy.

This proposal presented in Working Papers 2 and 3 extends the "international standards" defined by ICAO to cover domestic flights as well. Most developed countries are moving in this direction. The result is more observations and the provision of more services with greater accuracy throughout all economic sectors of the country.

In order to accomplish these goals, there will need to be a significant transition to increased automation in the meteorological system, from observations to data distribution, analysis, product generation, and dissemination to end users. Automated systems will provide around-the-clock observations with fewer trained observers, while using the existing staff to put a new emphasis on maintenance, forecasting, pre-flight briefing, and in-flight briefing. With the introduction of automated, self-service weather briefing stations, full weather services could be extended to every controlled airport.

With full access to automated products over the Web, every pilot with an Internet connection could obtain a weather briefing.

This transition represents an important element for change in Colombia. This change is fully consistent with the future enhancements to aviation services expected from the meteorological aspects of the upcoming CNS/ATM improvements. These include more data, fully networked communication links, improved data access, and better visualization and displays for all weather reports.

Forecasters in the system will be able to make intelligent decisions regarding en route products with improved time and space specificity. This would allow forecasts and warnings to be focused on air traffic needs and would include developing product formats and communications that easily fit within the ATC system.

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Appendix A: Inter-Agency Agreement between AeroCivil and IDEAM

TYPE OF CONTRACT: *INTERADMINISTRATIVE COOPERATION FRAMEWORK*

PUBLIC ENTITIES:

SPECIAL ADMINISTRATIVE UNIT OF CIVIL AVIATION "AEROCIVIL"

INSTITUTE OF HYDROLOGY, METEOROLOGY AND ENVIRONMENTAL STUDIES "IDEAM"

OBJECTIVE: *UNITE EFFORTS TO GUARANTEE DEVELOPMENT OF THE AERONAUTICAL METEROLOGY SERVICE*

DURATION: *FIVE YEARS*

Among those subscribed is ***JUAN CARLOS VELEZ URIBE***, of age, a neighbor of Bogotá, D.C., identified with citizen identification No. 70563378, issued in Envigado, and acting as General Director of the ***Special Administrative Unit of Civil Aeronautics***: A Specialized Entity, of technical character, assigned to the Ministry of Transportation, with legal status, administrative autonomy, and independent patrimony, appointed by Order No. 062 of January 17, 2001, and certificate of appointment 794 of February 20 of 2001, which for the effects of this contract will be denoted as ***AEROCIVIL***.
On the other hand is ***CARLOS CASTAÑO URIBE***, of age, identified with citizen identification No. 79140135, issued in Usaquén, in his quality as Director and Legal Representative of de ***Institute for Hydrology, Meteorology and the Environment "IDEAM:"*** Public establishment assigned to the Ministry of the Environment, created by Law 99 of 1993, regulated by Order 1352 of July 06, 2001, and Certificate of Appointment 026 of July 06, 2001, will be denoted as ***IDEAM***, have mutually convened this ***INTERADMINISTRATIVE AGREEMENT*** with the following considerations:

1) The ***Special Administrative Unit of Civil Aeronautics*** has compromised to adopt the norms and methods for the services of aeronautical meteorology contained in Annex 3 of the Chicago Agreement.

2) The ***Special Administrative Unit of Civil Aeronautics*** is responsible for safeguarding adherence to international precepts in aviation, and the security that must rule in aerial operations.

3) Annex 3 of the Chicago Agreement, referring to the meteorological service for international aerial navigation, determines that it is possible to obtain information from

the meteorological authorities of each State, maintaining a close relationship between users and providers of meteorological data.

4) The meteorological authorities seek to provide information on climatic or meteorological conditions in terminals, and on-route, such as, upper level winds and temperature, direction and maximum intensity of winds, and altitude of the tropopause in a convenient manner, as well as all the forecasts, regarding climatic phenomena, that of significant. Such an activity is provided through world, regional, and local forecasting centers that prepare and obtain pertinent information for on-flight needs.

5) In the case of aviation, the aspects related to the provision of meteorological information is perfectly described in Chapter 4, Annex 3 of ICAO, conforming to observations and meteorological reports, including meteorological stations, observations and ordinary reporting, special observations, observations and notifications of surface winds, anything referring to visibility of the runway, clouds and air temperature, dew point, as well as any supplementary information.

6) Information generated by meteorological stations of altitude and surface, satellite information, information received through the World Area Forecasting System (WAFS), information received from World Meteorological Centers, information received from the System of Aeronautic Communications, as well as on-flight observations used to enable the production of meteorological reports of METAR terminals, TAF forecasts, sigmet information or airdrome, winds, and upper level temperatures.

7) Aeronautic Meteorology was under the authority of civil aviation in its time, thereafter the Colombian Hydrological and Meteorological Service was created, subsequently the Institute of Hydrology, Meteorology and Land Adaptation (HIMAT), with whom the Administrative Department of Civil Aeronautics (DAAC) celebrated an agreement on March 5, 1990, that continues after 12 years.

8). In the agreement cited above a shared system for the collection of information to facilitate the services of the Special Administrative Unit of Civil Aeronautics (UAEAC) was established.

9) Colombia, by way of the ratification of the Agreement established by the World Meteorological Organization (WMO), acquired international compromises, particularly those related to the "Technical Regulations, Volume II, Meteorological Aerial International Navigation Services."

10) Law 99 of 1993 establishes that the IDEAM is in charge, among other functions, of obtaining, analyzing, studying, processing, and disseminating national meteorological data, as well as establishing national meteorological infrastructure to provide information, forecasts, warnings, and advice to the community.

11) Order 1277 of 1994 organizes and establishes the Institute of Hydrology, Meteorology, and Environmental Studies (IDEAM), regulating and establishing the

national meteorological structure, as well as the competence for offering meteorological services demanded by different socioeconomic sectors.

12) IDEAM is the national meteorological authority and the official representative of Colombia before the World Meteorological Organization (WMO).

13) ICAO accepts the principle to share meteorological services and initially setting forth an inventory of all the services and meteorological facilities used to satisfy all aviation necessities and of working in conjunction with aviation and meteorological authorities to determine the cost analysis of all the services that are provided by the different actors within the system.

14) Article 33 of Order 1277 of 1994 establishes that: "State entities of any order and scope that make use of the services provided by IDEAM should assign the economic resources, in each budget term, destined to cover the costs of services provided."

15) Given the particular functions of the two state institutions, and the necessity to rely on quality meteorological service, in order to guarantee aviation security within the national territory and in international compromises, as well as the obligation to optimize the usage of State resources in the offering of this service, it has been accorded to hold the present agreement to strengthen the IDEAM from a technical, scientific, and administrative viewpoint, and offer its users a better aeronautic meteorological component within the services provided by UAEAC. Having said this, the parties agree to hold the following inter-administrative agreement, which will be governed by the following ***Clauses***:

FIRST CLAUSE: OBJECTIVE: The present agreement has the objective to unite efforts to develop activities of mutual interest in different aspects unique to the functions of both institutions, as well as to guarantee the development of a continuous, coordinated, and reliable aeronautic meteorological system in the national territory. The system will stimulate the growth in demand for air transit and will also guarantee the rational use of resources by means of executing a joint investment program to avoid duplicating efforts and resources.

SECOND CLAUSE: CONTRIBUTION TO THE AGREEMENT: The Technical Committee, by means of the Annex approved by both parties, determines the individual contributions for the development of the present agreement.

THIRD CLAUSE: CREATION OF THE JOINT ADMINISTRATIVE COMMITTEE: The Joint Administrative Committee will be integrated by the Directors of both Institutions. This committee will be in charge of the orientation and the analysis of the performance of the aeronautical meteorological service, offering strategic political guidelines for the development of the agreement. The committee will adjourn biannually unless, by mutual agreement of both parties, more meetings are deemed necessary. The Technical Aeronautic Secretary of UAEAC will be invited to these meetings, and he will act as secretary of the committee and will be in charge of the appropriate Acts. The deputy director of meteorology of IDEAM will also assist.

FOURTH CLAUSE: FUNCTIONS OF THE JOINT ADMINISTRATIVE COMMITTEE:

a) Coordinate general politics regarding aeronautical meteorology in both institutions.
b) Arrange and approve programs and initiatives presented by the technical committee, and forward these to each organization in charge.
c) Implant within the institutions, the appropriate dispositions necessary to assist airships encountering intense meteorological phenomena.
d) Adhere to procedures that ensure that meteorological information is available in a suitable manner and according to air transit situations.

FIFTH CLAUSE: TECHNICAL COMMITTEE FOR AERONAUTIC METEOROLOGY: This committee will be integrated by two (2) members, of administrative and assistance levels, appointed by the Director of each institution, and with the knowledge and capacity to undertake compromises of the respective Entity in the adoption of recommendations, and fulfilling assigned obligations. The committee will hold at least one meeting per trimester.

SIXTH CLAUSE: FUNCTIONS OF THE *TECHNICAL COMMITTEE FOR AERONAUTIC METEOROLOGY:*

a). Design a timetable of work to be executed by AeroCivil and IDEAM.
b). Recommend the course of action to be taken with respect to joint programs and projects that are a priority.
c). Propose the joint program of aeronautical meteorology, to be approved by the Joint Administrative Committee. The program will describe activities for personnel training and proposals for technological development and service modernization. The text for the program will be attached with the present agreement and can be amended if necessity should require it, but only with the approval of the Joint Administrative Committee.
d). Evaluate the most adequate alternatives for the retribution of the services of aeronautical meteorology provided by IDEAM, by way of the AeroCivil, and propose the possible formulas to the Joint Administrative Committee for the adoption of those services.
e). Develop quality control of the aeronautical meteorological service provided and advice on pertinent recommendations.
f). Inform all interested parties of any inconveniencies that arise in the execution of the agreement in written form, and to propose solutions.
g). Follow up on the work program and its execution.
h). Invite experts and advisors to the meetings as the need arises.
i). Implement the new methods and technologies proposed by the World Meteorological Organization (WMO) and the International Civil Aviation Organization (ICAO) for the provision of the aeronautical meteorology service.
j). Functions assigned to the technical committee by the Joint Administrative Committee.

Specific obligations assigned to AeroCivil include the following:

a). Supply IDEAM with all the information in its data archives and other systems and meteorological sensors that are available.
b). Allow the use of communication networks, when available, for the transmission of messages and information related to aeronautical meteorology.
c). Facilitate the provision of meteorological services in different stations or airports in the country needed to assist aviation crews.
d). Facilitate the installations of CEA for the development of training in aeronautical meteorology specializations.
e). Supervise the quality of the aeronautical meteorology service and compile, and process complaints made by the users of such service.
f). Diffuse meteorological information through the WEB page of the Entity or establish the appropriate links to the web pages determined by IDEAM.
g). When possible, notify IDEAM, in due time and within reasonable time frame, the extension and modification in schedules, as well as the opening of meteorological services for aerial navigation in airports under the jurisdiction of AeroCivil.
h). In the case that the administration of an airport is delegated to an entity different from AeroCivil, the former will be in charge of notifying all airport operators about such an agreement and of all other decisions that follow.
i). Take into consideration, in planning and budgeting, the resources that in the Administrative Committee's consideration, correspond to the recognition of the provision of aeronautical meteorology services.

Specific obligations assigned to IDEAM include the following:
a). Offer the aeronautical meteorological service in those places determined by the Technical Committee, with approval from the Administrative Committee.
b). Arrange the necessary trained human resources to offer the service within established schedules.
c). Allow the use of information in their data archives, remote sensing systems, and all sources of information considered necessary to offer the service in conformity with Annex 3 of ICAO, as well as all the international standards and recommendations in the matter, in addition to those established by AeroCivil.
d). Give appropriate use to all resources and contributions made by AeroCivil within the framework of the agreement.
e). Take the obligations associated with the Aeronautical Meteorology Service into consideration in its annual planning.

The provision of services generated as a result of the present agreement, or of its annexes, does not constitute a working relationship between the participant parties, nor with the personnel employed for the fulfillment of objective activities. It is the exclusive responsibility of each party to employ the necessary personnel to execute the agreement. Each party supplies its personnel with all available and pertinent reference and background material for the provision of services, as well as all authorizations, use of installations, approvals, services, permits, and logistic support required to carry out its functions.

When necessary, annexes deemed important can be established to develop specific projects, as long as they are within the scope of the agreement and with prior approval from the Administrative Committee. The Technical Committee oversees the annexes mentioned above to ensure conformity to the objectives, the duration, the financial resources, the material media and human resources, as well as the adequate coordination, execution, and follow-up of the project. The annexes are approved by the Judicial and Legal Offices, or Directorates, of each institution, and also, by the corresponding planning authorities as well.

Considering the scarcity of secondary education centers in aeronautical and meteorological disciplines for the personnel that maintains the aviation meteorological services program in the Republic of Colombia, AeroCivil and the IDEAM have agreed to promote specialization in the subjects, by way of the Aeronautical Studies Center (CEA), and to incorporate it as direct technical assistance for the Technical Committee. The parties ensure, that whenever possible, the personnel receiving training under the agreement will continue to apply the knowledge within the organizations. The beneficiaries of this agreement are: a) Segments of aviation requiring modernization in order to gain access to the new technologies. b) Inhabitants of the Colombian territory that will benefit from the sustainable, planned meteorological development, its aeronautical component, and aviation. c) All sectors involved in civil aviation activities.

APPENDIX B: Sample Development Schedule

The following is a sample schedule that could be followed to implement a Colombian Aeronautical Meteorological Center. The schedule is meant to be suggestive only, at this point, and is not yet a firm proposal of activities.

Action	Duration	Start	End
Agreement to Proceed	66d	Mon 1/2/06	Mon 4/3/06
External Conference	0d	Mon 7/10/06	Mon 7/10/06
Phase 1 Plan	40d	Tue 8/1/06	Mon 9/25/06
Numerical Forecast Computing Center Plan	40d	Tue 9/26/06	Mon 11/20/06
Lightning Detection Network Plan	40d	Tue 9/26/06	Mon 11/20/06
2 Personnel to FAA FSS school	120d	Tue 9/26/06	Mon 3/12/07
Reg. Training for 1 MWO	180d	Tue 9/26/06	Mon 6/4/07
Interim Director Selected	1d?	Mon 1/8/07	Mon 1/8/07
Planning staff selected	20d	Tue 1/9/07	Mon 2/5/07
Annual and Planning Budget developed	0d	Mon 2/5/07	Mon 2/5/07
Personnel Plan written	60d	Mon 2/5/07	Fri 4/27/07
Maintenance Plan written	60d	Mon 2/5/07	Fri 4/27/07
2 Personnel to FAA FSS school	120d	Mon 3/26/07	Fri 9/7/07
Airport Met Networking Upgrade begins	168d	Wed 5/2/07	Fri 12/21/07
Forecast Workstations procured	120d	Wed 5/2/07	Tue 10/16/07
Lightning Detection Network established	170d	Wed 5/2/07	Tue 12/25/07
GOES system procured	170d	Wed 5/2/07	Tue 12/25/07
"SDMs, SOPs, Training manuals"	168d	Wed 5/2/07	Fri 12/21/07
Num. Forecast Computer Center Established	0d	Tue 5/1/07	Tue 5/1/07
Staffing identified for NFCC	60d	Wed 1/2/08	Tue 3/25/08
Maintenance Personnel in place	60d	Wed 1/2/08	Tue 3/25/08
Flight Folder Program Modernized	60d	Wed 1/2/08	Tue 3/25/08
Met Watch and SIGMETs	60d	Wed 1/2/08	Tue 3/25/08
2 Personnel to FAA FSS school	120d	Wed 1/2/08	Tue 6/17/08
2 Personnel to FAA FSS school	120d	Wed 6/18/08	Tue 12/2/08
Reg. Training for 1 SKBO MWO	180d	Wed 1/2/08	Tue 9/9/08
Airport Met Networking Continues	253d	Wed 1/2/08	Fri 12/19/08
Lightning Detection Network installed	254d	Wed 1/2/08	Mon 12/22/08
Development of Products for ATC`	120d	Wed 1/2/08	Tue 6/17/08
Software Template for SIGMETs	60d	Wed 1/2/08	Tue 3/25/08
NFCC begins operation	0d	Wed 1/2/08	Wed 1/2/08
Procurement begins for preflight system and software	254d	Wed 1/2/08	Mon 12/22/08
Briefing Training program written	120d	Wed 1/2/08	Tue 6/17/08
Software Templates for AIREPs	60d	Tue 4/1/08	Mon 6/23/08
FSS begins operations	0d	Tue 7/1/08	Tue 7/1/08
Communication Upgrade continues	253d	Wed 1/2/08	Fri 12/19/08
NFCC begins guidance operations	254d?	Mon 1/5/09	Thu 12/24/09

Procurement of pre-flight workstations	254d	Mon 1/5/09	Thu 12/24/09
User Workstation equipment staged	254d	Mon 1/5/09	Thu 12/24/09
2 Personnel to FAA FSS school	120d	Mon 1/5/09	Fri 6/19/09
2 Personnel to FAA FSS school	134d	Mon 6/22/09	Thu 12/24/09
Reg. Training for 1 MWO	180d	Mon 1/5/09	Fri 9/11/09
48 TAFs sent by CAMC	0d	Mon 2/2/09	Mon 2/2/09
Communication Upgrade continues	253d	Mon 1/5/09	Wed 12/23/09
Airport Met Networking Continues	253d	Mon 1/5/09	Wed 12/23/09
Lightning Detection Network installed	254d	Mon 1/5/09	Thu 12/24/09
Plans begin for central CAMC facility	0d	Mon 1/4/10	Mon 1/4/10
2 Personnel to FAA FSS school	120d	Mon 1/4/10	Fri 6/18/10
2 Personnel to FAA FSS school	135d	Mon 6/21/10	Fri 12/24/10
Reg. Training for 1 MWO	180d	Mon 1/4/10	Fri 9/10/10
Procurement of pre-flight workstations	254d	Mon 1/4/10	Thu 12/23/10
Reg. Training for 1 MWO	180d	Mon 1/4/10	Fri 9/10/10
Lightning Detection Network completed	254d	Mon 1/4/10	Thu 12/23/10
Communication Upgrade continues	253d	Mon 1/4/10	Wed 12/22/10
Airport Met Networking Continues	253d	Mon 1/4/10	Wed 12/22/10
CAMC Plans finalized and budgeted	0d	Mon 1/3/11	Mon 1/3/11
Procurement of pre-flight workstations	254d	Mon 1/3/11	Thu 12/22/11
2 Personnel to FAA FSS school	120d	Mon 1/3/11	Fri 6/17/11
2 Personnel to FAA FSS school	135d	Mon 6/20/11	Fri 12/23/11
Reg. Training for 1 CAMC Met	180d	Mon 1/3/11	Fri 9/9/11
Communication Upgrade continues	253d	Mon 1/3/11	Wed 12/21/11
Airport Met Networking Continues	253d	Mon 1/3/11	Wed 12/21/11
Contract Award and Construction begins on CAMC central facility	255d	Mon 1/2/12	Fri 12/21/12
Procurement of pre-flight workstations	255d	Mon 1/2/12	Fri 12/21/12
2 Personnel to FAA FSS school	120d	Mon 1/2/12	Fri 6/15/12
2 Personnel to FAA FSS school	120d	Mon 6/18/12	Fri 11/30/12
Reg. Training for 1 CMAC Met	180d	Mon 1/2/12	Fri 9/7/12
Doppler Weather Radar Installation begins	255d	Mon 1/2/12	Fri 12/21/12
Communication Upgrade continues	255d	Mon 1/2/12	Fri 12/21/12
Airport Met Networking Continues	253d	Mon 1/2/12	Wed 12/19/12
Construction continues on CAMC facility	255d	Wed 1/2/13	Tue 12/24/13
Management team selected for CAMC	255d	Wed 1/2/13	Tue 12/24/13
Procurement of pre-flight workstations	255d	Wed 1/2/13	Tue 12/24/13
2 Personnel to FAA FSS school	120d	Wed 1/2/13	Tue 6/18/13
2 Personnel to FAA FSS school	120d	Mon 6/24/13	Fri 12/6/13
Reg. Training for 1 CMAC Met	180d	Wed 1/2/13	Tue 9/10/13
Communication Upgrade continues	255d	Wed 1/2/13	Tue 12/24/13
Doppler Weather Radar Installation continues	255d	Wed 1/2/13	Tue 12/24/13
Airport Met Networking Continues	253d	Wed 1/2/13	Fri 12/20/13
Construction completed on CAMC facility	255d	Thu 1/2/14	Wed 12/24/14
Procurement of pre-flight workstations	255d	Thu 1/2/14	Wed 12/24/14

2 Personnel to FAA FSS school	120d	Thu 1/2/14	Wed 6/18/14
2 Personnel to FAA FSS school	120d	Mon 6/23/14	Fri 12/5/14
Reg. Training for 1 CMAC Met	180d	Thu 1/2/14	Wed 9/10/14
Doppler Weather Radar Installation continues	255d	Thu 1/2/14	Wed 12/24/14
Communication Upgrade continues	255d	Thu 1/2/14	Wed 12/24/14
Airport Met Networking Continues	253d	Thu 1/2/14	Mon 12/22/14
Management begins working for CAMC	148d	Mon 6/2/14	Wed 12/24/14
CAMC begins Formal Operation	0d	Mon 1/5/15	Mon 1/5/15
Procurement of pre-flight workstations completed	255d	Fri 1/2/15	Thu 12/24/15
2 Personnel to FAA FSS school	120d	Mon 1/5/15	Fri 6/19/15
2 Personnel to FAA FSS school	120d	Mon 6/22/15	Fri 12/4/15
Reg. Training for 1 CMAC Met	180d	Mon 1/5/15	Fri 9/11/15
Doppler Weather Radar Network completed	255d	Fri 1/2/15	Thu 12/24/15
Communication Upgrade continues	255d	Fri 1/2/15	Thu 12/24/15
Airport Met Networking Continues	253d	Fri 1/2/15	Tue 12/22/15

Appendix C: WMO Guidelines for Meteorological Expertise

The following material discusses the new classification system implemented by WMO, as well as matters of education and training. References to this material can be downloaded from:
http://www.wmo.ch/web/etr/classif.html

On the Design and Implementation of the new WMO-No. 258

Guidelines for the Education and Training of Personnel in Meteorology and Operational Hydrology
(Briefing Note by the Education and Training Department of WMO)

1. Goals, structure and content

Following the well-established tradition of the previous editions of WMO-No. 258, these *Guidelines* are aimed at assisting educators (and managers) in designing and implementing programs for human resources development, particularly in national Meteorological and Hydrological Services (NMHS) from developing countries. Whilst fostering innovation and adaptation to national/local circumstances, these Guidelines are aimed also at facilitating common understanding and a degree of uniformity and stability in an international context.

The potential user of these Guidelines (e.g. educators, managers, students) should be aware that the current issue departs considerably from its predecessors both in structure and content, and moreover in the spirit of its implementation. The new structure assumes issuing two separate volumes: Vol. I -*Meteorology* and Vol. II *Operational Hydrology*; and chapters' design is different from the previous edition. As for the content (of the first volume), a few new features may be highlighted.

Chapter 1: The new classification system (with two main categories of personnel and three career levels) is simpler and more flexible than the traditional classification; moreover it applies unitarily to both meteorological and hydrological personnel.

Chapter 2: More emphasis is put now on the job-competency requirements - both basic competencies for the job-entry-level, and specialized competencies for the actual practice at the current-operations-level. Identifying these competencies is the first step in establishing the requirements in terms of knowledge and skills.

Chapter 3: The multitude of meteorological disciplines and sub-disciplines is now treated within a simpler structured approach with four main disciplines from which derive many specialties. No attempts were made to describe each individual specialty since the Guidelines would have become too detailed and difficult to be managed, and moreover, in just a few years many specialty-descriptions would become outdated; see also item

(v) under the next section.

Chapters 4 and 5: Curricula for the initial formation of personnel are consistent with the job-entry-level requirements and with the new classification, i.e. there is a Basic Instruction Package for Meteorologists (BIP-M) and another "package" for Meteorological Technicians (BIP-MT). It is supposed that the substance of the BIP topics will change only little over a time period of the order of a decade (i.e. the assumed lifetime of these Guidelines).

Chapter 6: Since continuing education and training (CET) will be given much more emphasis than in the past, several methods and strategies for CET are presented in relation with common needs of a NMHS. The learning organization and continuing professional development concepts and the lifelong learning culture are emphasized.

Chapter 7: As the BIP-M and BIP-MT from Chapters 4 and 5 present only a minimum framework curricula for the initial qualification of meteorological personnel, the real-life examples from this Chapter could facilitate a more complete picture of the actual organization of the teaching programs.

Chapter 8: Eight examples of actual job-competencies, with relevant knowledge and skills in the main operational branches of activity, are provided. This approach was preferred to the detailed presentation of 16 fields of specialization from the previous edition, where the treatment of the individual fields of specialization was somehow unbalanced, and some unavoidable overlapping and gaps were apparent.

2. Implementation constraints and prospects

There are certain implications, challenges and opportunities relating to the actual implementation of the new edition of WMO-No. 258, in particular:

i. The new classification of personnel will enter into force starting from 1st January 2001, and accordingly, the former WMO Classes I to IV will be gradually replaced (but not later than 1 January 2005) by the new categories.

ii. Once the mission and major functions of the given NMHS are well established, the branch decomposition approach suggested in the Guidelines may be utilized to facilitate the identification of job-competency requirements. Innovative adaptation may have to be made by the potential user (e.g. NMHS' managerial team, including the chief of the training unit) in order to address all NMHS needs.

iii. Whereas the curricula from the previous edition was rather comprehensive and even prescriptive, now the lists of topics from the BIPs are only indicative for the minimum curricula subjects that must be acquired by a student in order to qualify for the job-entry-level, and eventually to be recognized by WMO. (Such recognition would be needed, for example, when evaluating the prerequisite qualification of candidates for WMO fellowships and specialized training events). The user (e.g. professor in the Meteorological Department of a University) may expand the BIP content by deepening the study of certain topics or by broadening the interdisciplinary treatment within the approach of earth system science.

iv. The examples given in Chapter 8 are meant to inspire educators and managers in identifying NMHS' requirements for specialized knowledge and skills, and then to translate those requirements in terms of training outcomes. The user may have to adapt those examples to his specific priorities. Accordingly, various topics may receive more or less emphasis than suggested in those examples. It could be that some examples might not even apply to the given NMHS (e.g. a land-locked country may not be interested in marine meteorology).

v. Noting that today many job-competencies, and the related specialized knowledge and skills evolve very rapidly, rather than attempting short-lived descriptions of meteorological specialties within WMO-No. 258 proper, these Guidelines will be complemented by a new WMO publication Continuing Education and Training in Meteorology and Hydrology. This new CET-MH Series will be issued periodically and will consist of up-to-date review papers on specialized "hot subjects", recommended by the WMO Technical Commissions, or other relevant bodies. Tentatively, the first title in the new publication will be issued by mid 2001 and will address the Satellite Meteorology specialty.

vi. WMO may also utilize Internet resources (Virtual Training Library) to facilitate Members' efforts for the appropriate implementation of the new WMO-No. 258.

Appendix D: ICAO and WMO Regional Training Centers in Latin America

ICAO Region South America (SAM)

Aeronautical Meteorological Courses offered by the Training Centers of Civil Aviation of Region SAM

Servicio Meteorológico Nacional (SMN)
25 de Mayo 658, Capital Federal, 1002 Buenos Aires, ARGENTINA
Tel.: (5411) 4514-4253
Fax: (5411) 4514-4225

Dirección General de Aeronáutica Civil
Escuela Técnica Aeronáutica
Av. Portales 3450, Santiago, CHILE
Tel.: (562) 681-5966
Fax: (562) 681-7670
E-mail: dgaceta@transtar.cl y cursint@uplink.cl

WMO Regional Association III (South America)

Argentina:

Departamento de Ciencias de la Atmósfera, Facultad de Ciencias Exactas y Naturales
Universidad de Buenos Aires,
Ciudad Universitaria - Pabellón 2,
1428 BUENOS AIRES,
Argentina
Tel: (54-11) 4576 33 56 EXT 17
Fax: (54-11) 4576 33 64
E-mail: gardiol@at1.fcen.uba.ar
Internet: www-atmo.at.fcen.uba.ar

Departamento Instruccion
c/o Servicio Meteorológico Nacional,
Av. de los Constituyentes 3454
1427 BUENOS AIRES,
Argentina
Tel: (54-11) 4514 80 67
Fax: (54-11) 4514 42 25
E-mail: emartinez74@yahoo.com

Internet: www.meteofa.mil.ar

Brazil:

Universidade Federal do Pará, Departamento de Meteorología, Centro de Geociencias
Campus Universitário do Guamá, Caixa Postal 1611, CEP 66050 BELEM, Pará
Brazil
Tel: (55-91) 229 20 88
Fax: (55-91) 211 16 09
E-mail: midori@ufpa.br
Internet: www.ufpa.br/cg/DM.htm
Telex: 911013 BELEM

Venezuela:

Departamento de Meteorología e Hidrología
Facultad de Ingeniería, Universidad Central de Venezuela
Ciudad Universitaria, CARACAS
Venezuela
Tel: (58-2) 605 30 49
Fax: (58-2) 605 30 39
E-mail:asalcedo@reacciun.ve

WMO Regional Association IV (North and Central America)

Barbados:

Caribbean Institute for Meteorology and Hydrology (CIMH)
P.O. Box 130, BRIDGETOWN
Barbados
Tel: (1-246) 42 51 362 /63 /65
Fax: (1-246) 42 44 733
Internet: www.inaccs.com.bb/Carimet

Costa Rica:

Lab. de Investigaciones Atmosféricas y Planetarias Escuela de Física
Universidad de Costa Rica
2060 SAN JOSE
Costa Rica
Tel: (506) 207 53 94, 207 51 42
Fax: (506) 207 56 19
E-mail: wfer@ariel.efis.ucr.ac.cr
Internet: www.efis.ucr.ac.cr

Appendix E: Selected References for Training Materials

Selected WMO publications of interest:

For WMO publications see the web site: http://www.wmo.ch/index-en.html

114 - Guide to qualifications and training of meteorological personnel employed in the provision of meteorological services for international air navigation

240 - Compendium of education and training facilities for meteorology and operational hydrology

258 - Guidelines for the education and training of personnel in meteorology and operational hydrology
(multiple volumes)

266 - Compendium of lecture notes for training Class IV meteorological personnel
(multiple volumes)

364 - Compendium of meteorology for use by Class I and Class II meteorological personnel
(multiple volumes)

622 - Compendium of lecture notes on meteorological instruments for training Class III and Class IV meteorological personnel
(multiple volumes)

669 - Workbook on numerical weather prediction for the tropics for the training of Class I and Class II meteorological personnel

701 - Mesometeorology and short-range forecasting-Lecture notes and students' workbook for training Class I and Class II meteorological personnel

726 -Compendium of lecture notes in climatology for Class III and Class IV personnel

Hong Kong Meteorological Training

Hong Kong is active in providing WMO meteorological training. They also have a nice web site that discusses some of the courses they offer. The web site is:
http://www.hko.gov.hk/wservice/tsheet/metrain.htm

United States Meteorological Training

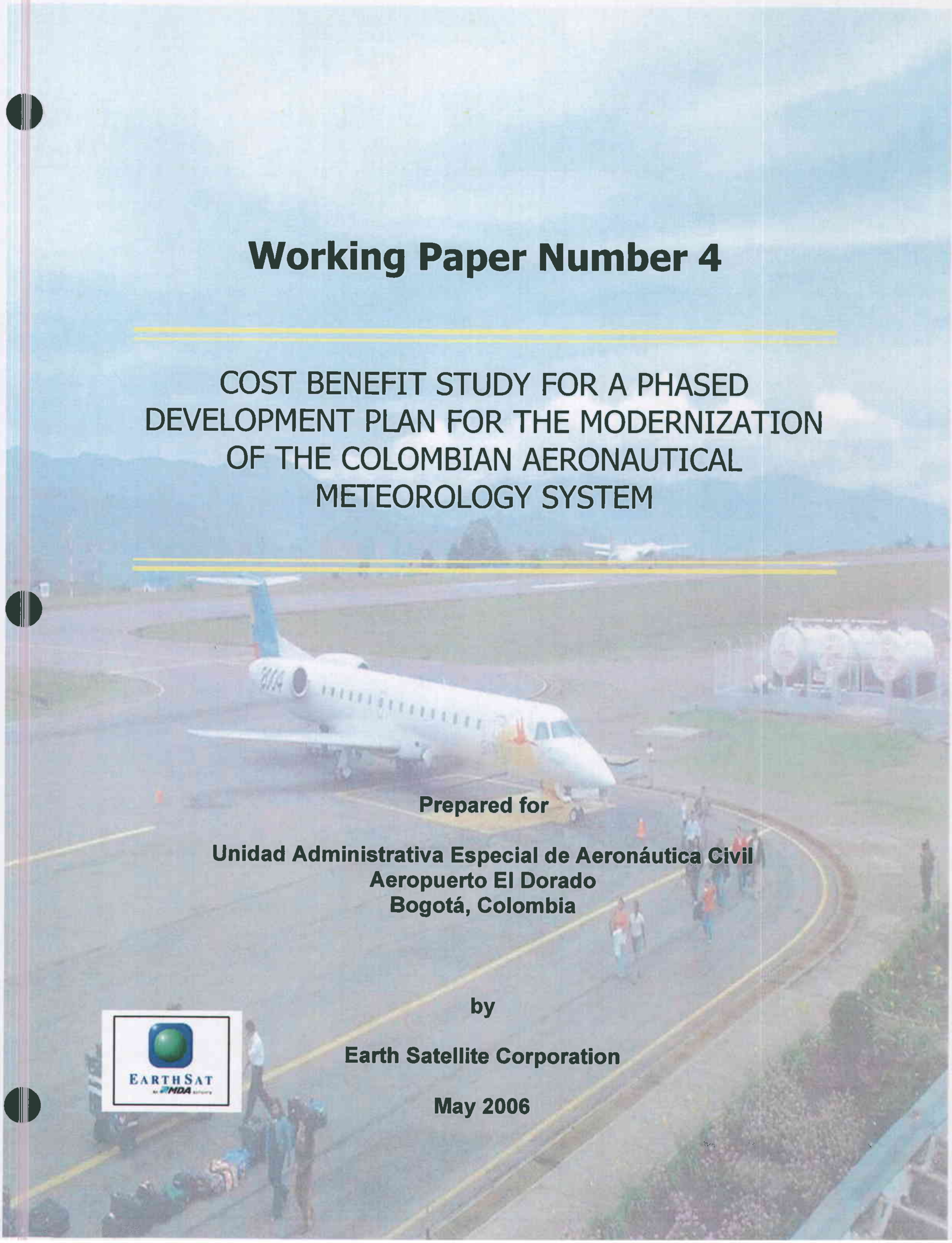
COMET (Cooperative Program for Operational Meteorological Education and Training) is a program operated by the University Corporation for Atmospheric Research under sponsorship by the NWS and military weather services. COMET has a variety of online and distance learning programs, many now translated into Spanish.

http://www.comet.ucar.edu/

COMET cooperates actively with the WMO and has prepared many of their training materials into Spanish language versions.

The current listing of courses in Aviation Meteorology is available at the following link:

http://meted.ucar.edu/topics_aviation.php



Working Paper Number 4

COST BENEFIT STUDY FOR A PHASED DEVELOPMENT PLAN FOR THE MODERNIZATION OF THE COLOMBIAN AERONAUTICAL METEOROLOGY SYSTEM

Prepared for

Unidad Administrativa Especial de Aeronáutica Civil
Aeropuerto El Dorado
Bogotá, Colombia

by

Earth Satellite Corporation

EARTHSAT

May 2006

Table of Contents

1 INTRODUCTION

1.1 Scope of the study and background

The scope of Working Paper 4 is described in the Terms of Reference as follows.

"A cost benefit analysis will be conducted by the Consultant to determine the best options for the investment plan. The Consultant will develop a year-by-year investment plan. The Consultant shall develop Cost Recovery Guidance. The Consultant shall study the environmental impact of the options. The Consultant shall provide a list of U.S. suppliers of equipment and systems. "

As requested, the EarthSat team has conducted a cost benefit analysis of the phased development plan for modernization of the Colombian aeronautical meteorological system. We begin by summarizing the Tasks 1, 2, and 3 Working Papers to document the current state of meteorological support for aviation and proposed future enhancements. To create the cost benefit analysis we first identify all of the proposed actions and costs from the reports for Tasks 2 and 3, and develop the base assumptions for the analyses in this Working Paper. Next we developed three potential implementation options and created the year-by-year investment plan, cost recovery guidance and an environmental analysis for each option. Finally, we developed a list of qualified U.S. companies that could provide the necessary equipment and systems to perform the modernization.

1.2 Colombian aviation authority and weather information service

In Colombia, the Unidad Administrativa Especial de Aeronáutica Civil (UAEAC, also termed UAEAC) is the cognizant civil aviation authority. The UAEAC shares the responsibility for the provision of aeronautical weather information with the Colombian national weather service, IDEAM (Instituto de Hidrología, Meteorología y Estudios Ambientales), through a signed interagency agreement. Over the last several years, plans have progressed in Colombia for a transition to new communication, navigation, and surveillance technologies (CNS/ATM) that will meet the demands of current and future air traffic levels and safety standards. The concepts of CNS/ATM will permit aircraft to fly in any type of airspace, and operate with reduced separations in existing airspace. Given that such a system will place higher demands on the availability of accurate, easily available, real-time weather information and weather forecasts, UAEAC is aware of the need to modernize its aeronautical meteorological system, and has requested assistance in developing a prioritized ten-year plan to accomplish this.

1.3 Colombia's position within the South American air traffic system

As described in Working Paper 1, Colombia is located at a critical spot in South America, with some 70% of the flights from Central and North America crossing Colombian air space on their way to other South American destinations. These flight operations involve aircraft from a large number of countries, so it is important to maintain a common set of international standards for aeronautical meteorology. Typical over-flight routes from the southeast, such as those from Brazil and Argentina, pass over Leticia in the south of Colombia toward San Andreas in the Caribbean northwest of the Colombian mainland, and then proceed northbound to Miami.

Flights originating in countries to the south, such as Ecuador, Peru, and Chile, tend to over-fly the western off-shore air space of Colombia.

1.4 Geography of Colombia

The geography of Colombia is quite varied. Tropical conditions exist in the north part of the country and the Caribbean, mountainous regions with high valleys associated with several mountain chains that are oriented roughly northeast-southwest through the central part of the country, and tropical lowlands and jungle over the large southeastern part of the country. This general physiography is illustrated in Figure 2.1, which also shows a number of important cities and airports where METARs and other climatological information are recorded.

1.5 Weather issues affecting aviation in Colombia

With the high humidity that exists over most of the country and the strong orographic influences, the diurnal changes in weather are very large, and weather forecasting is a particularly important, as well as particularly challenging, problem. Reduced ceiling and visibility is a problem all over Colombia in association with heavy rain and thunderstorms, and a number of airports are particularly impacted by fog, mist, and drizzle. Hurricanes usually stay north of the Colombian mainland, but can occasionally affect the coast of northern Colombia with strong winds (Cartagena and Barranquilla). On average, every five to eight years the Caribbean islands of San Andrés and Providencia are impacted by tropical storms and hurricanes that can shut down the airports for extended periods.

Strong, gusty winds are recognized as a problem at Cartagena and Barranquilla on the north coast, and at Leticia in Amazonas. Cúcuta and Bucaramanga also report problems with strong winds and turbulence around the airport. Shifting winds and turbulence are also known to be particular problems at two airports, Pasto and Providencia. Turbulence at en-route flight levels is a result of both convective storm activity and clear air turbulence. Both are commonplace in Colombia.

Volcanic ash is a serious safety issue for aircraft that inadvertently fly through ash plumes. Several volcanoes exist around the region and occasionally affect the airspace over Colombia. The accretion of ice on aircraft flying through super-cooled liquid clouds occasionally occurs in convective clouds in Colombia, but most of the people interviewed do not consider it to be a critical problem.

2 CURRENT STATE OF METEOROLOGICAL SUPPORT FOR AVIATION AND PROPOSED FUTURE ENHANCEMENTS

2.1 Colombian Airports and Services

Currently, seven airports are equipped for instrument landings (ILS Categories I and II), and two additional airports are being upgraded to ILS service in the near future (arrows in the ILS Category column in Table 2.1. indicate planned enhancements).

Only five Colombian airports operate around the clock. The remaining controlled airports (43 in all) are restricted to daytime and early evening operations – generally from 0600 to 1800 local time.

Terminal area forecasts (TAFs) are issued for seven of Colombia's eight international airports. The one exception is Cúcuta, located in northeastern Colombia at the Venezuelan border.

With only two exceptions, Corozal and Mariquita, all of the UAEAC controlled airports make weather observations and issue hourly METARs during their hours of operation. Radiosondes are launched at three airports. There is also a sounding system at a fourth airport, Riohacha, but that system is not currently in use. Radiosondes are released once a day at approximately 0630 local time for the official 12Z sounding.

At 27 of the 45 controlled airports that issue METARs, IDEAM provides MET services with full-time, trained meteorological observers according to the interadministrative agreement. At the remaining 18 airports, the METARs are generated by UAEAC staff who have been trained as weather observers through the AIS/COM/MET Integral course. However, taking weather observations is a collateral, or secondary duty. In many of these cases, the tower controllers prepare the METARs. The three right-hand columns in Table 2.1 summarize the number of IDEAM MET staff assigned to each airport, the total number of UAEAC (with AIS, COM, and MET responsibilities), and the number of UAEAC staff who are directly involved in making meteorological observations and preparing METAR reports (including part time assignments).

Figure 2.1 Map of Colombia illustrating topographic variations and the location of principal airports. Note that the position and size of the islands of San Andrés and Providencia are not shown to scale.

regional	siglas	AEROPUERTO	2003 Operations	ILS Category	Airport Hours	ATC Controlled	MET Hours	12 Z Radiosonde	TAF	METAR	Aerocivil AIS/COM/MET	Aerocivil MET Staff	IDEAM MET Staff
Antioquia	SKMD	MEDELLIN ✓	82,426		0600-1800	X	0600-1800			IDEAM	8		3
	SKRG	**RIONEGRO*** INTL ✓	45,113	Cat I → II	24	X	24		X	IDEAM	8		5
	SKUI	QUIBDO ✓	13,002		0600-1800	X	0600-1800			IDEAM			2
	SKMR	MONTERIA	12,012		0600-1900	X	0600-1800			IDEAM	1		3
	SKLC	CAREPA (Los cedros) APARTADO	11,504		0600-1800	X	0600-1800			IDEAM	2		2
	SKMZ	MANIZALES	9,831		0600-1800	X	0600-1800			UAEAC	2	1	
	SKBS	BAHIA SOLANO	4,057		0600-1800	X	0600-1800			UAEAC	2	1	
Atlantico	SKCG	CARTAGENA INTL ✓	31,634	→ Cat I	24	X	24		X	IDEAM	5		6
	SKBQ	**BARRANQUILLA*** INTL ✓	26,559	Cat I	24	X	24		X	IDEAM	13		5
	SKSM	SANTA MARTA	12,768		0600-2200	X	0600-2200			IDEAM	2		3
	SKSP	SAN ANDRES INTL ✓	12,153	→ Cat I	0600-2400	X	0600-1800	X	X	IDEAM	3		5
	SKVP	VALLEDUPAR	6,635		0600-1800	X	0600-1800			IDEAM			3
	SKCZ	COROZAL	4,848		0600-1800	X	—			—	2		
	SKPV	PROVIDENCIA ✓	3,132		0600-1800	X	0600-1800			IDEAM	2		2
	SKRH	RIOHACHA	2,176		0600-1800	X	0600-1800	X		IDEAM			2
Bogota	SKBO	**BOGOTA D.C.*** INTL ✓	195,734	Cat I & Cat II	24	X	24	X	X	IDEAM	4	1	23
	SKGY	GUAYMARAL ✓	60,472		0600-1800	X	0600-1800			UAEAC	2	1	
	SKGI	GIRARDOT	19,360		0600-1800	X	0600-1800			UAEAC	2	1	
	SKIB	IBAGUE	18,658		0600-2000	X	0600-2000			IDEAM	1		2
	SKNV	NEIVA	18,193		0600-2000	X	0600-1800			IDEAM	2		3
	SKQU	MARIQUITA	17,725		0600-1800	X	—			—	2		
	SKAS	PUERTO ASIS	6,900		0600-1800	X	0600-1800			UAEAC	2	1	
	SKFL	FLORENCIA	6,688		0600-1800	X	0600-1800			UAEAC	1	1	
	SKSV	SAN VICENTE DEL CAGUAN	3,046		0600-1800	X	0600-1800			UAEAC	2	1	
	SKLT	LETICIA INTL ✓	2,640	Cat I	0600-2000	X	0600-2000	X	X	IDEAM	1		4
Valle	SKCL	**CALI*** INTL ✓	46,279	Cat I	24	X	24		X	IDEAM	11		5
	SKPE	PEREIRA	22,199		0600-2200	X	0600-2200			IDEAM	4		3
	SKAR	ARMENIA	10,739		0600-2100	X	0600-2100			IDEAM	2		3
	SKPS	PASTO ✓	7,646	→ Cat I	0600-1800	X	0600-1800			IDEAM			2
	SKPP	POPAYAN	7,458		0600-1800	X	0600-1800			UAEAC	2	1	
	SKCO	TUMACO	5,715		0600-1800	X	0600-1800			UAEAC	2	1	
	SKCO	CARTAGO	3,298		0600-1800	X	0600-1800			UAEAC	2	1	
	SKIP	IPIALES	1,396		0600-1800	X	0600-1800			IDEAM			3
	SKGP	GUAPI	1,152		0600-1800	X	0600-1800			UAEAC	2	1	
	SKBU	BUENAVENTURA	1,034		0600-1800	X	0600-1800			UAEAC	2	1	
Santander	SKBG	BUCARAMANGA ✓	27,614	→ Cat I	0600-2200	X	0600-2200			IDEAM	5		4
	SKCC	**CUCUTA*** INTL ✓	15,056	Cat I	0600-1900	X	0600-1900			IDEAM	3		3
	SKEJ	BARRANCABERMEJA	10,157		0600-1800	X	0600-1800			IDEAM			3
	SKUC	ARAUCA	9,878		0600-2000	X	0600-1800			IDEAM	2		2
	SKSA	SARAVENA	5,905		0600-1800	X	0600-1800			UAEAC	2	1	
	SKTM	TAME	2,945		0600-1800	X	0600-1800			UAEAC	2	1	
	SKOC	OCANA	879		0600-1800	X	0600-1800			UAEAC	2	1	
Meta	SKVV	**VILLAVICENCIO*** ✓	39,828		0600-1800	X	0600-1800			IDEAM	4		3
	SKYP	EL YOPAL	29,967		0600-1900	X	0600-1800			UAEAC	2	1	
	SKSJ	SAN JOSE DEL GUAVIARE	16,047	Cat I	0600-1800	X	0600-1800			UAEAC	2	1	
	SKMU	MITU	5,463		0600-1800	X	0600-1800			UAEAC	2	1	
	SKPC	PUERTO CARRENO	822		0600-1800	X	0600-1800			IDEAM	2		2
			829,379								124	19	106
Private	SKLM	La Mina (CERREJON)			0600-2100	X							

*Regional Center ✓ Identifies airports visited by EarthSat team Note: Riohacha radiosonde station is not in active use

Table 2.1. Summary information for controlled airports in Colombia

2.2 Current status of airport instruments and operating systems

2.2.1 Tower Instruments and MET Gardens

Virtually all controlled Colombian airports have some combination of three different basic observing systems. The most basic airport MET system in Colombia consists of windsocks along the runway, a tower altimeter, and an anemometer (indicating wind speed and direction) mounted on top of the control tower. At larger airports where IDEAM staff members are assigned, there are frequently special instrument enclosures called MET Gardens that are used for making routine synoptic observations. In the current basic configuration these are all manual observing stations with hourly observations made by qualified observers. It is not always easy to find clear open spaces at the airports, so these instrument sites often do not have ideal exposure and do not meet ICAO standards.

2.2.2 Automatic Meteorological Observation Systems (AWOS)

In recent years, some of the airport MET Gardens have been enhanced by the addition of elementary automatic weather stations supplied by Sutron Corporation. These enhanced systems make automatic observations of temperature, pressure, and wind (direction and speed), and relay the measurements to the airport weather office via a radio link. The principal value of these automatic systems is that the observers do not have to go outside to make a reading. The automatic systems are installed within the existing MET Garden and include a standard height 10-meter tower for wind measurements. The system includes a PC-based system unit installed in the weather office that displays the real-time data and provides software to assist the observer in generating correctly formatted METARs. Unfortunately, the observers do not always trust the new systems and rely mostly on the old manual systems (Section 4.2.1, Working Paper 1).

Several years ago, Aero Civil installed new Sutron automatic weather stations at 12 Colombian airports. These newer observing systems have been installed at more appropriate locations near the runway, though not always near the touchdown point. The Sutron automated weather stations installed at a number of UAEAC airports are designed to emulate the capabilities of an AWOS-1 station. Annex 3 (ICAO, 2001) also mandates that METARs include reports of visibility and cloud cover (cloud type, amount, and base height), although these measurements can be added manually.

They are also equipped with VHF ATIS radios for short-range transmission of METARs to nearby aircraft. These new Sutron systems also support duplicate displays of the weather observations through PC's installed in the airport Control Tower and Approach Control.

In the "family" of eight different AWOS systems, from AWOS-1 to AWOS-4, these systems would be classified as AWOS-1 systems. AWOS-1 contains sensors for pressure, wind, temperature, and dew point. At many airports in Colombia it would be beneficial to upgrade the automatic weather stations to AWOS-3 class installations, adding visibility and cloud height (ceilometer) measurements that would be processed and displayed using the same integrated workstations. AWOS-3 sensors would then have sensors for pressure, wind, temperature, dew point, cloud height and visibility.

2.2.3 General Conditions and Age

Meteorological equipment in Colombia spans a wide range of ages and conditions. Many of the MET instruments installed in airport control towers have been in place a long time, frequently as long as 25 years. For the most part, however, these older systems seem to be working well. "MET Garden" instrumentation appears to be even older than most of the control tower sensors. The basic tower instrumentation only needs to be replaced if the instruments show clear signs of being defective or become impossible to be maintained because replacement parts or regular maintenance supplies are no longer available.

2.2.4 Ceiling and Visibility Measurement

Runway Visual Range (RVR) measurements are essentially high-quality runway visibility observations designed for use in times of restricted visibility. By ICAO standards, they should be accompanied by automatic ceilometer systems for measuring cloud base heights. RVR systems are typically installed in pairs, with one set of sensors monitoring the visual range at each end of the runway, and may be further enhanced with an additional RVR at center field. If instrumented landings are only conducted in one direction, a single sensor installation could be acceptable. One of the major Colombian deficiencies is a failure to implement all required RVR systems. During visits to 15 Colombian airports, we did not identify any fully operational RVR or ceilometer systems. Installation of the required RVRs should be a high priority.

2.2.5 Radiosondes

Colombia has five upper-air sounding sites and all are important. At present, only three of these stations appear to be launching radiosondes, and even these stations do not necessarily launch a sounding every day. Only a limited number of radiosondes are taken due to the cost of the sondes. The relatively limited use of upper-air soundings by forecasters is a weakness, and the initial goal of the upgrade should be to get all five of these systems back into operation with a single sounding (at 12Z) from each station. The longer term goal should be to maintain the one-a-day launch schedule from four stations while adding a second balloon launch every day in Bogotá – fulfilling Colombia's WMO commitment.

2.2.6 Situational Awareness

One of Colombia's critical needs is to build "situational awareness," which means understanding the current state of the atmosphere. This includes standard surface airport condition measurements at airports throughout the country, as well as knowing the position and movement of fronts, air mass boundaries, inversions, tropopause height, areas of fog and low cloud, the locations and expected growth of convective systems and thunderstorms, areas of heavy rain, locations of clear air and convectively induced turbulence, in-flight icing, and volcanic ash.

Remote sensing systems are particularly valuable in this regard, including imagery from meteorological satellites, weather radars, and plotted observations from lightning detection networks.

SIGMETs and AIREPs are essential for safe air navigation, but are seldom, if ever, issued in Colombia. The lack of resources to issue SIGMETs and AIREPs creates a major deficiency that compromises aviation safety. Changing the status quo will require training, reviews of guidelines and procedures for issuing SIGMET and AIREP reports, and expanded observational and operational capabilities. SIGMETs, in particular, require a good situational awareness of areas of hazardous weather. Operationally, there is also a need for computer-assisted templates for preparing AIREPs and SIGMETs that will facilitate the rapid preparation of the reports, combined with networked workstations that can transmit the reports via the AFTN and Washington WAFS uplink without them having to be retyped.

There needs to be an allocation of resources towards routine issuance of SIGMETs, improved forecasts, and better briefing materials. This will require increased reliance on automatic observing systems to give MET staff time to perform new duties, and the development of a higher-level, professional meteorological staff. Improvements to the aeronautical meteorological system will also require additional equipment upgrades, enhanced communication facilities, and expanded use of networked observing systems and workstations

2.2.7 Meteorological satellite data acquisition and processing system

The GOES-12 satellite provides uniform coverage over all regions of the country at least once every 30 minutes, 24 hours per day, and monitoring the satellite imagery is an effective way to gain a good situational awareness of the evolving weather systems over the entire country and surrounding airspace at modest cost. Full resolution, highest-quality digital data stream GVAR data from the GOES satellite produces simultaneous imagery in five wavelength bands, ranging from 1 km resolution visible imagery to 4 km resolution infrared and water-vapor imagery. In addition to the full GVAR data stream, lower resolution subsets of GOES data are available through WEFAX or LRIT transmissions. The older, analog WEFAX broadcast is being discontinued in favor of the new, digital, LRIT transmission. Except as a backup system, WEFAX or LRIT receiver systems are not needed if there is access to the full GVAR data stream.

The OPMET Forecasting Center at Bogotá's El Dorado Airport can view GOES/GVAR imagery from a GVAR receiving system located at IDEAM's offices in downtown Bogotá via the IDEAM web page. UAEAC also receives its own GOES/GVAR imagery from a newly purchased receiving system from IPS MeteoStar located at the airport, but the IDEAM forecasters do not use this data.

2.2.8 Meteorological radars

At present there are no civilian weather radars in Colombia. Colombia does, however, have a full ATC radar network that covers the entire country. ATC radars frequently have a "weather channel" that can be used to identify areas of precipitation, but the weather products produced by such systems are usually unsatisfactory and can often be misleading.

An individual weather radar can be used to provide coverage over a terminal approach area and, if properly positioned and supplied with suitable processing software, may be able to detect and identify the areas of convective windshear in the airport area. For broader coverage, it is necessary to network a number of radars, sharing data to produce radar mosaics. Based on a comparison with U.S. radar coverage, it is estimated that full weather radar coverage of Colombia would require 15, if not more, radars.

2.2.9 Lightning detection networks

Colombia currently has two small networks of cloud-to-ground lightning detectors, one installed by Interconexión Eléctricia S.A. (ISA), and a more limited system operated by a regional power company in Medellín (EEPPM). These power companies are considering upgrading their cloud-to-ground systems to current standards and may add additional sensors, which offers a unique opportunity for UAEAC to work with these power systems and other potential participants to develop a national network of lightning detection. These systems can now be used to display real-time tracks of lightning activity, effectively identifying the active cores of thunderstorms and giving an indication of the growth and decay. A lightning detection network designed to extend the coverage supplied by the existing systems to provide coverage over all of Colombia may require 20 to 25 additional detectors distributed throughout the country.

2.2.10 Wind Shear Detection

Strong, gusty winds and turbulence are recognized as problems at Cartagena, Barranquilla, Leticia, Cúcuta, Bucaramanga, Providencia and Pasto (most severely). In large part, these winds and turbulence seem to be terrain induced. This means that the major commercial windshear detection system, such as LLWAS would not be appropriate. In many of Colombia's most problematic airports it would be very difficult to install a true LLWAS system. One option that may be appropriate would be to install an extended network of anemometers along the runway and at critical terrain features surrounding the airport. EarthSat recommends that UAEAC respond to the call for installing windshear systems at Pasto and other Colombian airports through the installation of a custom surface weather and wind monitoring system consisting of a central automatic weather station with at least three anemometers along the runway, augmented by perhaps four or more additional anemometers installed at critical terrain features away from the airport property.

EarthSat also recommends that UAEAC acquire a single tethersonde system for conducting special studies of the wind patterns around Pasto and other airports with terrain induced turbulence and windshear problems. This system would be used to help understand the complex wind environments around these airports and can be moved from airport to airport. This system would not be part of an operational airport system.

2.2.11 Maintenance and calibration

Perhaps the most serious problem uncovered during review of the Colombian aeronautical meteorology system has been the lack of suitable attention to maintenance and sensor calibration. Proper system maintenance, including an adequate schedule of preventive maintenance, will ensure the availability of reliable, accurate measurements. This will also translate into longer system lifetimes and lower replacement costs. A comprehensive maintenance program will require a significant budget, but may well save money in the long run.

2.2.12 Communications, processing, and distribution of real-time observations

Currently, data collection and distribution are labor-intensive activities requiring multiple manual entries of data or reports into separate workstations or communication ports. For efficiency and reliability, EarthSat recommends that Colombia upgrade its observation and data distribution systems to make greater use of a networked communication environment. With the anticipated consolidation of all airport observing systems under UAEAC, the meteorology offices should be fully integrated into the existing airport communication systems.

Currently, not every controlled airport has access to the AFTN for distribution and reception of METARs, SPECIs, and TAFs. The aging AFTN system may well need an upgrade, but this will have to be done in concert with international standards, recommendations, and the general structure of the system. In planning for future upgrades, every controlled airport should be expected to need AFTN access or other ways of sending and receiving OPMET messages through complimentary network communication links. In the long term, UAEAC should also plan to upgrade digital communication links to provide two-way, high-speed, broadband data links to all controlled airports.

At the present, most airport MET offices are not fully integrated into the UAEAC airport communication systems and have to access the Internet via commercial dial-up lines. Improved access to Internet connectivity is likely to become an important issue as additional data sets and large image files are broadcast in support of enhanced pilot briefing systems.

2.2.13 Data exchange with en-route aircraft - uplinking and downlinking digital weather data from en-route aircraft

At present, EarthSat does not recommend that Colombia try to implement its own system of automatic weather data uplinks or downlinks to en-route aircraft. Other priorities are more pressing.

2.2.14 Data integration workstations for forecasting and aeronautical climatology studies

Modern weather forecasting is increasingly being done using computer workstations to display and analyze the weather. These workstations integrate observations, numerical model results, satellite imagery, and other available resources with capabilities to overlay different data sets and perform time animations. In the workstation environment, the emphasis is on graphical analysis for easy visualization of the overall weather situation. At present, most of the weather data available to Colombian forecasters are provided by the international WAFS data transmissions combined with local observations that are not transmitted internationally, and basic satellite imagery.

At a basic level, a simple or enhanced commercial WAFS workstation may provide significant data integration and display capabilities. Some commercial WAFS systems are even able to enhance the WAFS data sets with locally acquired satellite data or other data sets (see Section

4.13 in Working Paper Number 2). More sophisticated systems are usually developed as custom packages that depend on specific, locally available data sets.

2.2.15 Accessing WAFS data sets

The Colombian WAFS system has been managed and operated by IDEAM. The system provided to Colombia consists of a 2-way VSAT communication system coupled to a Global Science & Technology (GST) "MetLab" WAFS workstation. The workstation integrates data reception, display, analysis, and can be extended with optional pilot briefing packages. Aviation and weather data received via the WAFS system is sent to the forecast center at El Dorado airport as the primary source of weather information for Colombia's aviation forecasts.

UAEAC has very recently acquired an additional WAFS system from IPS MeteoStar in order to provide for independent access to WAFS aviation data sets and products.

2.2.16 Software templates for AIREPs, SIGMETs, and other routine reports

Preparation of SIGMETs and AIREPs can be time consuming and difficult. To encourage aviation forecasters to issue these warnings and reports it is important to conduct regular training for procedures and standards, and to make the preparation of these warnings and reports as easy as possible. One way to do this is to provide computer-assisted software templates that help format the warnings and reports and get them ready to transmit. Stock phrases can be preprogrammed and entered into the preformats with the click of a mouse. Times and dates can be entered automatically. In a sophisticated system, locations could be identified by the click of a mouse on a computerized aviation map or current satellite image. Templates of this sort should be considered an essential part of a weather data integration and forecaster workstation (see Sections 4.11 and 4.12 in Working Paper Number 2), but could also be run as a stand-alone application.

2.2.17 Numerical weather prediction model development

Numerical weather prediction models are valuable tools for anticipating future weather trends and are essential for modern weather forecasting. Model output fields can already be received through the ICAO-sponsored WAFS data stream from Washington. These models, which are run at the World Area Forecast Center in Washington, DC, frequently have had difficulties in tropical areas near the equator and have not been heavily used in Colombia.

Part of the difficulty in Colombia is the dramatic influence of terrain, land surface properties, and localized moisture sources. Modern mesoscale numerical models are designed to handle these small-scale, local features and assist the forecaster to make more accurate forecasts. Under most circumstances these models are run locally, but they could also be run by a foreign company or institute. EarthSat recommends that UAEAC take the lead in a multi-agency collaboration to help develop high-resolution, mesoscale weather prediction models for Colombia and northwestern South America.

2.2.18 Pre-flight briefing systems

At present, pre-flight information exchange usually consists of being handed printouts of METARs and a TAF, if available. Pilot briefings and even casual discussion between pilots and airport MET staff appear to be limited to unusual events. Developing graphical briefing materials that are custom designed for the task will be more effective and have a greater impact. When presented on computer workstations, large format display screens can make the materials easier to see and discuss.

EarthSat recommends that UAEAC make a special effort to develop high-quality briefing products and systems to serve the Colombian aviation community, eventually at every controlled airport. While there are several approaches to presenting the briefing materials, we are impressed with the capabilities demonstrated by web-based technologies, such as ADDS, and encourage Colombia to explore that option first. ADDS-style systems are well suited to incorporate local forecast models that can generate aviation-specific weather information. In the Colombian environment, we recommend that the briefing materials be delivered over a secure, internal, airport communication rather than opting for full public access over the Internet.

Web-based weather information services can be designed to incorporate features such as airport web cameras, rapidly updated weather information from all airports (updates every 5 minutes) that can be used to generate time series plots, and a central data base for airport operational status. Web cameras installed at airports would allow pilots and ATC personnel to actually see the local conditions at a destination airport rather than just depend on numerical products and data summaries.

2.2.19 Communication upgrades

UAEAC has recently completed upgrading many of its communication systems. In developing the current system, little provision was made for weather data transmission. In large part, this merely reflects the current weather observation system, which is based on short text messages that do not present any difficulties to even relatively low bandwidth communications.

Our 10-year plan for upgrading Colombia's aviation weather system will dramatically increase weather data transmissions through expansion in the use of satellite imagery, weather radars, lightning detection networks, numerical weather prediction models, and sophisticated pre-flight briefing workstations at every controlled airport. These new systems will require significant upgrades to the UAEAC communication systems.

Perhaps the most critical improvement needed is to upgrade the AFTN system to allow controlled network access from secure computers and workstations through a modern TCP/IP communication protocol (see Section 4.10 in Working Paper Number 2). This upgrade would also be consistent with the ongoing ICAO/SAM REDDIG initiative, which seeks to transition the system's current serial protocol landline transmissions to satellite-based TCP/IP transmission. Within Colombia, the basic AFTN functionality could then be concentrated at a few central sites with service to outlying airports being provided through standard, secure, upgraded network communication links. Since the AFTN message traffic would still be text based, this change would not require a major increase in bandwidth or system throughput, although other data sets and transmission will require significant increases in bandwidth (see Sections 2.2.12 and 2.2.19, above).

2.2.20 Staffing

The vast majority of the meteorological staff working at Colombian airport meteorological offices and the Bogotá Meteorological Watch Office are classified as observers, many of whom have performed the same job for 15-20 years. These observers have shown great loyalty and dedication in staying with their jobs this long, even without opportunities for training or professional advancement. These staff members represent an untapped resource that could be used to increase the number of more highly trained MET staff. With the eventual introduction of advanced observational systems and improved meteorological briefing materials, it will become increasingly important to develop personnel to fill more high-level meteorologist positions. The most efficient way to fill these positions is through advanced training of existing staff members. The staff upgrades should be based on an improved program of professional education and training that permits existing observers to advance to higher-level positions.

3 PROPOSED ACTIONS AND COSTS

3.1 Initial costs and Vendors

3.1.1 Initial cost estimates

General cost estimates for equipment, installation and support, shown in Table 3.1 below, are taken from the text in Section 4, Working Paper 2, Infrastructure Options and Observational Systems Upgrades.

EQUIPMENT, INSTALLATION AND SUPPORT	COSTS
AWOS systems	
AWOS-3 Purchase (for multiple units)	about US$ 65,000 – 75,000
Civil and electrical works	US$ 20,000
Installation	US$ 10,000
Total	just over US$ 100,000
Cost to duplicate single full-feature ASOS (not commercially available)	over US$ $300,000
High quality AWOS-1, limited processing capabilities (exclusive of installation and civil works)	US$ 30,000
High quality visibility sensors	US$ 10 –15,000
Ceilometers	more than US$ 20-25,000+
Overall cost of the comprehensive upgrade of the surface observing systems at all Colombian controlled airports (including civil and electrical works) – over 10 years	just over US$ 4,500,000
RVRs	
Transmissometer-based dual threshold	US$ 120,000
Single threshold	US$ 75,000
Installation, civil, electrical - per site	US$ 25-30,000
Forward scatter RVRs, pair	US$ 75,000
Single threshold	US$ 50-60,000
Install with civil, electrical works	US$ 20-25,000
Upgrades - overall cost (For acquisition of two new transmissometer-based RVR systems, plus seven forward-scatter RVR systems)	about US$ 480,000
For civil and electrical works and installation for all seven sites	about US$ 180,000
A companion ceilometer for new RVR systems in Bogotá (making use of existing displays)	US$ 30-40,000
Approximate Acquisition Cost (for planning purposes): total	US$ 700-800,000

EQUIPMENT, INSTALLATION AND SUPPORT	COSTS
National network for altimetric adjustment (not recommended)	
Fully automated weather systems (AWOS-A) - per site (plus installation and civil and electrical works.)	approx US$ 12,000
Equip with their own ATIS-style VHF radios - per installation	average US$ 5000-8000
Radiosondes and upper-air sounding systems	
MW15 upgraded to compatibility with the RS92 radiosondes	approx US$ 15,000
Upgrade from the MW15 to the MW21	approx US$ 120,000
Plus Full featured METGRAPH option	US$ 9,000
Upgrades	
Year 1 Acquisition - New MW21 (with METGRAPH) and Single MW15 upgrade (including a separate, stand-alone personal computer)	US$ 150,000
Year 2 Subsequent upgrade - 2 additional MW15 systems (+ two networked personal computers)	approx US$ 40,000
Continuing Annual Radiosonde Costs	
Single RS80 radiosondes (purchased in bulk)	approx US$ 140
Newer RS92 radiosondes- per radiosonde	perhaps US$ 180
For single site, single daily launch – per year	almost US$ 70,000
WMO program of six daily soundings – per year - (two daily Bogotá, one per day other four sites)	almost US$ 400,000
Meteorological Satellites GOES/GVAR	
Sophisticated, high-end systems	approx US$ 80,000-110,000
Midlevel systems depending on design and capabilities	$30,000 to US$ 60,000 and up
Software support contracts - per year	US$ 5,000 approx
Hardware support contracts	about 15% of the original system purchase price.
LRIT full digital processing systems	around US$ 30,000.
Approximate acquisition costs (for planning purposes) for LRIT	around US$ 30-40,000
High-end GOES/GVAR (as part of separate forecasters workstation procurement system)	US$ 80-110,000
Meteorological radars	
Approximate Acquisition Cost (for planning purposes)	US$ 2.5-3.0 million
Local infrastructure such as a building to house the radar, tower, radome, communication links, etc.	US$ Hundreds of thousands
Full software support agreement, per year	might cost US$ 10,000

EQUIPMENT, INSTALLATION AND SUPPORT	COSTS
Continuing annual support budget, over long term	averages at least 10% of original system cost
National lightning detection network	
For full national coverage, need roughly 30-32 stations	
National network designed in collaboration with ISA, require 25 additional sensors	
Equipment Costs, approximately - per site	US$ 100,000
Civil works and installation - per site	US$ 10,000
Central processing station	US$ 400,000
Year 2: Procure system, install command center and install 5 sensors in locations that can enlarge and expand the existing ISA detection network	US$ 1 million
Year 3: Install 10 systems. Estimated cost	US$ 1.2 million
Year 4: Install 10 systems. Estimated cost	US$ 1.2 million
Windshear detection & warning systems	
Commercial LLWAS system for convective windshear (Depending on the size of the airport and area covered)	approx US$ 1 million
Doppler lidars	start at around US$ 1.5 million
Boundary layer wind profilers	about US$ 350,000
Custom installation of multiple anemometers (including a standard, full-featured AWOS-3 equivalent system at the heart of the airport weather system)	about US$ 250,000
A complete, reusable tethersonde system	about US$ 80-100,000
Proposed schedule and acquisition costs	
UAEAC acquire three custom multi-anemometer wind monitoring systems estimated cost per airport	about US$ 250,000
Consultant installation design and customization	US$ 50,000 – 100,000 per airport, depending on complexity
Processing and distribution of real-time observations	
Each controlled airport will require one, on occasion, two, new computers per airport: Estimated average cost per airport	about US$ 6,000
Data integration workstations	
Forecaster workstation costs	US$ 100,000 and up

EQUIPMENT, INSTALLATION AND SUPPORT	COSTS
Software templates for SIGMETs, AIREPs	
Basic text-based templates with graphical interface	under US$ 100,000
Adding interactive graphical data displays	Could double cost
Accessing WAFS data sets	
WAFS workstation with VSAT communications (receive only)	US$ 75,000
Add up-link capability	about US$ 10,000
Analysis-only WAFS workstation (Without a VSAT communication link, but with number of optional analysis, integration, and display capabilities – including a pilot briefing module)	about US$ 80,000
Numerical weather prediction model development	
4-year start-up budget estimate (Exclusive of staff salaries - for analysis workstations, communication links, and the multi-processor modeling cluster)	US$ 1 million
Continuing maintenance and software support budget, per year	US$ 100,000
Periodic upgrades and replacements of the cluster components - every three years	estimated US$ 300,000
Foreign expert involvement in mesoscale modeling	approx US$ 200-400,000
Alternative: UAEAC initiates this modeling effort entirely through a private company or independent consultant with training and support. Budget each of first two years	US$ 1 million
Ongoing testing, improvement, and maintenance consultancy	US$ 300,000- 500,000 per year
Pre-flight briefing systems	
Reasonably full-featured update of the ADDS web system (exclusive of remote airport hardware and communication links.)	approx US$ 250,000
Web-based local workstations (Depending on the display requirements.)	US$ 2,500 to US$ 5,000
Total per airport computer systems upgrade cost (including upgraded airport weather systems and networking)	about US$ 10,000
Communication upgrades	
Estimated costs for upgrading MET communications per year over a ten-year period	US$ 50,000
Airport web cameras - Approximate acquisition costs, per airport	US$ 4000

Table 3.1 General cost estimates for planning.

3.1.2 Vendors

The following vendors, service companies and consulting firms have been cited in the text. The instruments listed and services described below are those mentioned in the text for each vendor and do not represent all the equipment a particular vendor makes or services a company provides. Addresses, phone and fax numbers of these vendors are listed in Appendix A.

All Weather, Inc.: AWOS, ceilometers, anemometers
ARINC, Inc.: Aircraft data exchange and digital data linking
Belfort Instruments: AWOS-2
CLR Photonics: Doppler Lidar
Coastal Environmental Systems, Inc.: AWOS, RVRs, anemometers, high quality calibration barometers.
Global Science and Technology (GST): GOES GVAR processing software MetLab WAFS workstations
Intermet: Radio theodolites
Microsoft Corporation: Software
ParoScientific: High quality calibration barometers
Potomac Aviation Technology Corp.: AWOS, AWOS-1
SeaSpace Corporation: GVAR satellite systems.
Sigmet, Inc.: Radar processing systems and displays
Sippican, Inc.: Upper air sounding systems.
Sutron Corporation: AWOS, anemometers
Teledyne Controls: RVRs
Vaisala: AWOS, ceilometers, DigiCORA radiosonde sounding systems, tethersondes, lightning detectors, LLWAS, anemometers, boundary layer wind profilers, high quality calibration barometers

4 Analysis of Organizational and Technical Options

In Working Papers 2 and 3, EarthSat outlined a "core" set of recommended upgrades to the Colombian aeronautical meteorology system, designed to be compliant with ICAO requirements and recommendations and responsive to users' needs. These upgrades involved both national level systems that can serve the entire country from a centralized location and individual airport system upgrades. The recommendations were carefully considered for their usefulness to Colombia and their cost efficiency, but were primarily based on meteorological and operational considerations. In addition to the "core" program, EarthSat also identified a number of additional recommended system enhancements that go beyond minimum ICAO standards and which could provide significant additional enhancements to Colombia's aeronautical meteorology system and better fulfill users' needs.

The primary purpose of Working Paper 4 is to examine the recommendations of the previous Working Papers from a financial and environmental viewpoint. After reviewing the core set of recommended upgrades, EarthSat decided that it would be beneficial to perform the analyses requested in Working Paper 4 using a stepwise approach. First, benefit/cost analyses for three technical implementation options that represent different levels of financial investment for UAEAC were investigated. The highest benefit/cost technical option was selected for further evaluation. For the technical option, with the highest benefit/cost ratios, five organizational options were investigated. The one with the highest benefit/cost ratio was selected for cost/recovery analyses. The option with the best cash flow was then selected as the recommended implementation.

The EarthSat team made the following assumptions in proposing these options:

- There will be sufficient funds available to meet the major goals for the final chosen option.
- There will be sufficient staff either currently on duty or trainable in time to operate the systems.
- There will be support from the Colombian government, and the organizational framework exists to make the suggested upgrades.
- The equipment will be available either now or within a selected time frame, as dictated by the implementation plan.
- There will be electrical power and backup power to operate systems that need it.
- Building space and the new sensor systems will have minor impacts on the environment or environmental impacts that can be easily mitigated.
- During the 10 years of the modernization implementation, the communication links between the controlled airports will be upgraded.

A summary table of benefit/cost for the technical options is presented in Table 4.1.

Option	Description	Value	Name of File Showing Calculation
1	Upgrade 16 airports	180	Tech_Option_1_Benefit_Cost_Analysis_Revised
2	Upgrade 48 airports	347	Tech_Option_2_Benefit_Cost_Analysis_Revised
3	Implement all items	247	Tech_Option_3_Benefit_Cost_Analysis_Revised

Table 4.1 Technical Benefit / Cost Ratio Calculations

Each of the files listed in Table 4.1 also contains benefit/cost calculations for each technical option using a net present value calculation assuming a 3% and a 5% discount rate. We selected these two discount rates to roughly model the current rate of inflation.

The first technical option is the base set of activities required for improving weather observations and the dissemination of information (TAFS and METARS) for 16 of Colombia's 48 controlled airports. These airports include the international airports, airports with instrument landing systems and airports with high traffic loads. International traffic entering Colombia or aircraft planning to use ILS category fields should have the best forecasts through the TAFs, which currently are not well regarded. In this option we also propose to improve SIGMET and AIREP information to ensure safe flights where hazardous conditions might exist. Option 1 is designed to allow UAEAC to view the financial impact of reducing the scale of the modernization. It is important to note, however, that if Technical Option 1 is implemented, it would not meet all of the users' needs identified in Working Paper 1, and 32 controlled airports would remain non-compliant with ICAO standards. This option was evaluated simply to provide UAEAC a low-cost solution should funding be restricted

The second option includes all 48 controlled airports. In particular, it adds AWOS-3 instruments to the 32 controlled airports not included in Option 1. This option represents the full "core" set of system upgrades proposed in Working Paper 2. Option 2 is ultimately the one recommended by the EarthSat team in Working Paper 4 because a number of the program elements shared by Options 1 and 2 are the same regardless of the number of airports served. Therefore, if the system is to be upgraded, it makes it possible for the Colombian aviation interests to have accurate weather information for all the controlled airports in the country, deriving the largest cost/benefit.

The third option is the most comprehensive (and most expensive) and follows all of EarthSat's recommendations as outlined in Working Papers 2 and 3, and shown in Table A-3 and in Appendix A in Working Paper 2. This includes the improvements proposed in Technical Options 1 and 2 and adds high budget systems such as lightning detectors, weather radars, and a mesoscale meteorological center. Figure 5.1 shows the airports included in each option, and the program elements for the respective options are provided in the following sections. It is important to note that there is a marginal increase in the benefit/cost ratio for each option so that every option is beneficial but the total benefit/cost ratio is reduced in technical option three when compared to technical option 2.

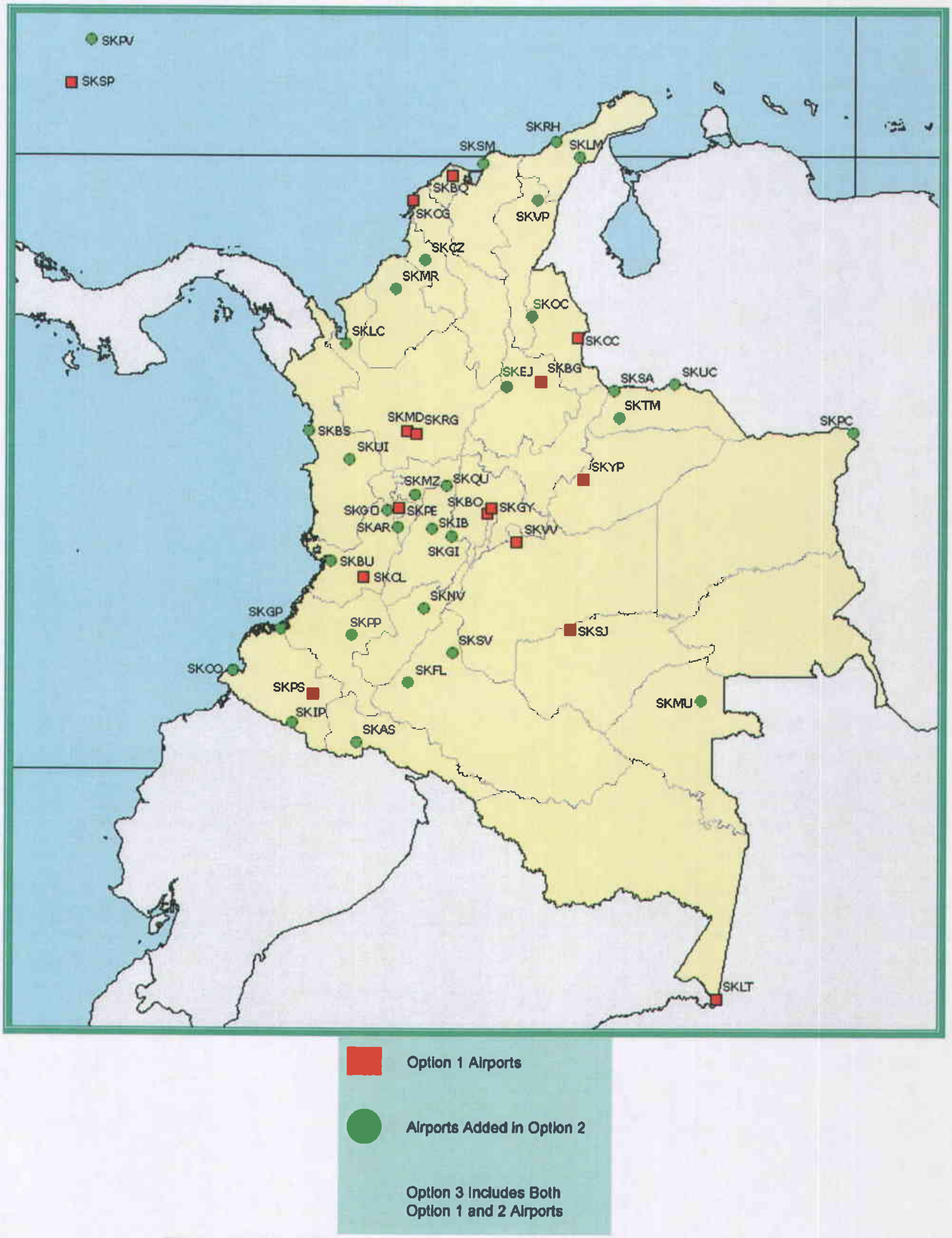


Figure 4.1. Map of the 48 controlled airports included in Options 1, 2 and 3.

4.1 Option 1

This option focuses on 16 controlled airports in Colombia that fit one or all of the following criteria: They receive international traffic, they have or plan to have instrument landing systems, and they have more than 20,000 operations per year. Detailed information on each airport included in Option 1 is presented in Table 4.2.

AIRPORT	2003 OPERATIONS	ILS CATEGORY	AIRPORT HOURS	MET HOURS	TAF	RADIOSONDE
MEDELLIN	82,426		0600-1800	0600-1800		
RIONEGRO* INTL	45,113	Cat I → II	24	24	X	
CARTAGENA INTL	31,634	→ Cat I	24	24	X	
BARRANQUILLA* INTL	26,559	Cat I	24	24	X	
SAN ANDRES INTL	12,153	→ Cat I	0600-2400	0600-1800	X	X
BOGOTA D.C.* INTL	195,734	Cat I & Cat II	24	24	X	X
GUAYMARAL	60,472		0600-1800	0600-1800		
LETICIA INTL	2,640	Cat I	0600-2000	0600-2000	X	X
CALI* INTL	46,279	Cat I	24	24	X	
PEREIRA	22,199		0600-2200	0600-2200		
PASTO	7,646	→ Cat I	0600-1800	0600-1800		
BUCARAMANGA	27,614	→ Cat I	0600-2200	0600-2200		
CUCUTA* INTL	15,056	Cat I	0600-1900	0600-1900		
VILLAVICENCIO*	39,828		0600-1800	0600-1800		
EL YOPAL	29,967		0600-1900	0600-1800		
SAN JOSE DEL GUAVIARE	16,047	Cat I	0600-1800	0600-1800		

* Regional Centers ——> Indicates upgrade to ILS or the next category of ILS

Table 4.2. The 16 controlled airports proposed under Option 1. The table shows that eight airports are international, seven have instrument landing systems and four are being upgraded to ILS service, two of these in the near future.

The specific program cost elements for Technical Option 1 are listed below and described in detail in the remainder of this section. Although Technical Option 1 does provide critical upgrades for 16 airports and lower the cost of the modernization, the cost savings are not as large as they could be because the expenditures associated with a number of the program elements are the same regardless of the number of airports served as indicated below in Table 4.3.

Program Element	Comments
Basic Control Tower MET Systems	
RVR and Ceilometers for ILS Runways	
A Comprehensive AWOS Replacement Program	
GOES Receiving Systems (2004 purchase)	
Radiosonde and Upper Air Soundings	Same cost in all options because the airports receiving upgrades are in all three options
WAFS Workstation (acquired in 2005)	
Airport MET Networking Upgrades	
Forecaster Data Integration Workstation	Same cost in all options because software development costs do not change with number of airports served
Software Templates for SIGMETs and AIREPs	Same cost in all options because software development costs do not change with number of airports served
Pre-flight (Pilot) Briefing System & Software	Same cost in all options because software development costs do not change with number of airports served
Local Pre-flight Weather Briefing, User Workstations	
Weather Systems for Calibration and Training	Same number of systems needed for 16 airports as 48

Table 4.3 Program Elements of Option 1

4.1.1 Automated Weather Observation Systems

Currently only five Colombian airports shown in Table 4.2 provide METARs 24 hours per day. To mitigate this shortcoming, we recommend the installation of automated meteorological observing stations at all 16 controlled airports (see 4.1.2). This will allow METARs to be generated 24 hours a day at all of these airports. In addition, EarthSat recommends that automatic observations of cloud ceiling and visibility be included in the basic observing station configuration, upgrading the recommended observing station standard to AWOS-3. The AWOS-3 instrument suites recommended for all of the controlled airport locations contain sensors necessary for measuring pressure, wind, temperature, dew point, visibility and cloud height, which are the basic parameters included in the hourly METAR reports.

In general there is a lack of confidence in the new observing systems. In part, this is due to a combination of maintenance problems, individual sensing systems that are broken or out of calibration, and readings that differ from system to system. Given the variability in the locations of these sensor packages, it is not surprising that the systems frequently give different readings. Therefore the requisite training needed to understand and maintain these systems and instill confidence in their operation is included in this option.

4.1.2 RVRs and ceilometers

In this option we recommend ensuring that RVR and ceilometers are installed and working at the airports that have instrument landing systems or are proposed to have them. In our experience visiting Colombian airports we discovered that most of these systems do not appear to be operational, and are frequently described by airport staff and pilots as "out of service." The lack of required RVR measurement systems was highlighted as a deficiency of the Colombian Aeronautical Meteorology system by the CAR/SAM Regional Aeronautical Meteorology Subgroup (Section 4.2.1, Working Paper 1). While Medellin is not a candidate for an ILS system, we recommend that ceilometers and visibility sensors (but not full RVR systems) be installed at each end of the runway because of the typical difficult weather conditions there. Runway visual range (RVR) and ceilometer systems installed at Colombian airports should not be operated as stand-alone systems, but should be integrated with the AWOS stations and included in the airport METAR reports.

4.1.3 Radiosondes

Colombia has five upper-air sounding sites in its national radiosonde network and all are important. As shown in Table 4.2, only three of these stations appear to be launching radiosondes, and even these stations do not necessarily launch a sounding every day. Technical Option 1 includes the equipment necessary to get all five of these systems back into operation with a single sounding (at 12Z) from each station.

4.1.4 Web Cameras

As a part of the Technical Option 1 upgrades, we also recommend that web cameras be installed at the selected airports to provide additional and relatively inexpensive real time aids in monitoring airport conditions for both pilots and forecasters.

4.1.5 Terminal Area Forecasts

Whereas METARs provide current airport information, TAFs add the forecasting element necessary for better flight planning. Presently there is widespread dissatisfaction with the quality of the TAFs. It was claimed they were not always current, and were sometimes completely wrong. International carriers, for example, generally said that they ignored the TAFs entirely and only looked at the METAR reports, and some international carriers obtained their weather forecasts from private commercial sources. TAFs are currently issued for seven of Colombia's eight international airports.

In this option we propose ensuring that the TAFs for the international and ILS category airports are prepared properly, and suggest that additional TAFs could be made at some of the high density airports in Colombia. We propose adding TAFS for all controlled airports in Technical Option 2.

4.1.6 SIGMETs and AIREPs

We propose that the effort to develop SIGMET warnings and AIREP reporting be part of this base recommendation option. Colombia needs to issue the required SIGMETs and AIREPs.

AIREPs should be relatively easy to implement since the formal reporting of written AIREPs is primarily a procedural and operational issue, not requiring any substantial reallocation of resources. Pilots already verbally report turbulence and other hazards to ATC, and these warnings are often transmitted verbally to other planes in the area. The remaining task is to transcribe these verbal reports into written records that can be entered into the AFTN system. The generation of written AIREPs can be facilitated through the use of computer-based templates for easy report preparation. Issuance of required SIGMETs will require observing system enhancements and additional specific forecaster training, as well as the development of computer-based templates.

4.1.7 Reducing Redundancy

We recommend improved reporting by finding methods of reducing redundancy in the way meteorological information is recorded and reported, and in the manner in which IDEAM and Aero Civil staff interact. Transition to a system with the necessary automation in the reporting process should, in part, accomplish this action. We also recommend developing improved WAFS Workstation, Airport MET Networking Upgrades, Forecaster Data Integration Workstations, Software Templates for SIGMETs and AIREPs, Pre-flight (Pilot) Briefing Systems and Software, Local Pre-flight Weather Briefing and User Workstations and Communication Upgrades (MET data distribution) at the selected airports.

4.1.8 Benefits

Technical Option 1 is expected to yield a saving of 16 observer position salaries by the end of 2014. Based on history, the equipment upgrades are expected to prevent one small aircraft each year and prevent one major airline crash during the ten-year period. These preventions would yield a savings of approximately 140 lives during the period. Productivity would increase 5% per year. Benefits due to efficiencies in aircraft operations are expected to yield 135,870 aircraft operations that will save on average 15 minutes. This results in significant savings to airlines and travelers as shown in the Technical Option 1 spreadsheet (See Appendix B).

4.2 Technical Option 2

This option represents the full "core" set of system upgrades proposed in Working Paper 2, and as such it meets all of users' needs identified in Working Paper 1, and all controlled airports are compliant with ICAO standards. Therefore Technical Option 2 includes equipment upgrades at all controlled airports, and EarthSat recommends the following program elements to accomplish this:

- Basic Control Tower MET Systems
- RVR and Ceilometers for ILS Runways
- A Comprehensive AWOS Replacement Program
- GOES Receiving Systems (2004 purchase)
- Radiosonde and Upper Air Soundings
- WAFS Workstation (acquired in 2005)
- Airport MET Networking Upgrades

- Forecaster Data Integration Workstation
- Software Templates for SIGMETs and AIREPs
- Pre-flight (Pilot) Briefing System & Software
- Local Pre-flight Weather Briefing, User Workstations
- Weather Systems for Calibration and Training

The detailed description of these program elements is provided in the previous section and the distribution of instruments at each airport in Technical Option 2 is presented in Table 4.4.

Airports Identified by Category, Operational Status, and Communication Links						Instrumentation and Observational Facilities					
AIRPORT	UAEAC CATEGORY	ICAO	ILS	HOURS	COM	WEATHER OBS	EXTRA SENSORS	WINDSHEAR SYSTEM	RVR & CEILOMETER	LIGHTNING SENSOR	[illegible]
BOGOTÁ	A-1	INTL	Cat I & II	24	HUB	AWOS-3	Optional-1		2X & 2X		X
CALI	A-1	INTL	Cat I	24	VSAT+MW	AWOS-3	Optional		X		X
RIONEGRO	A-1	INTL	Cat I → II	24	VSAT+MW	AWOS-3	Optional		2X		X
CARTAGENA	A-1	INTL	→ Cat I	24	VSAT+MW	AWOS-3	Optional		X		X
BUCARAMANGA	A-1		→ Cat I		MW	AWOS-3	Optional	X	X		X
BARRANQUILLA	A-1	INTL	Cat I	24	VSAT+MW	AWOS-3	Optional		X		X
PEREIRA	A-2				VSAT+MW	AWOS-3	Optional				
CUCUTA	A-1	INTL	Cat I		VSAT+MW	AWOS-3	Optional		X		X
SAN ANDRES	A-1	INTL	→ Cat I		VSAT	AWOS-3	Optional-2		X	Future	X
LETICIA	A-1	INTL	Cat I		VSAT	AWOS-3	Optional		X	X	X
VILLAVICENCIO NOTE 4	B-1				VSAT+MW	AWOS-3	Optional			X	
EL YOPAL	B-2				VSAT	AWOS-3	Optional			X	
NEIVA	B-3				VSAT	AWOS-3	Optional				
SANTA MARTA	B-2				MW	AWOS-3	Optional				
ARMENIA	B-3				MW	AWOS-3	Optional			X	
MANIZALES	B-2				VSAT	AWOS-3	Optional				
IBAGUE	B-3				MW	AWOS-3	Optional				
PASTO	B-3		→ Cat I		VSAT	AWOS-3	Optional	X	X		X
MONTERIA	B-2				VSAT+MW	AWOS-3	Optional			X	
CARTAGO	B-4				MW	AWOS-3	Optional				
IPIALES	B-4				VSAT	AWOS-3	Optional-1				
QUIBDO	B-5				VSAT	AWOS-3	Optional			X	
POPAYAN	B-3				MW	AWOS-3	Optional			X	
MEDELLIN	B-2				MW	AWOS-3	Optional-3				X
GUAYMARAL	B-2				MW	AWOS-3	Optional				
SAN JOSE DEL GUAVIARE	C-3		Cat I		VSAT	AWOS-3	Optional		X	X	X
BAHIA SOLANO	C-4				—	AWOS-3	Optional			Optional	
GIRARDOT	C-3				—	AWOS-3	Optional				
MARIQUITA	C-4				—	AWOS-3	Optional				
FLORENCIA	C-4				VSAT	AWOS-3	Optional				
CAREPA	C-2				VSAT	AWOS-3	Optional			X	
PUERTO ASIS	C-4				VSAT	AWOS-3	Optional			X	
VALLEDUPAR	C-3				VSAT+MW	AWOS-3	Optional			X	
MITU	C-4				VSAT	AWOS-3	Optional			X	
PROVIDENCIA	C-3				VSAT	AWOS-3	Optional-2	X		Future	X
RIOHACHA	C-4				VSAT	AWOS-3	Optional			X	
PUERTO CARREÑO NOTE 5	D-4				—	AWOS-3	Optional			X	
ARAUCA	D-2				VSAT+MW	AWOS-3	Optional			X	
BARRANCABERMEJA	D-2				MW	AWOS-3	Optional				
BUENAVENTURA	D-4				—	AWOS-3	Optional				
COROZAL	D-4				—	AWOS-3	Optional				
GUAPI	D-4				—	AWOS-3	Optional				
OCAÑA	D-4				MW	AWOS-3	Optional				
SAN VICENTE DEL CAGUAN	D-4				VSAT	AWOS-3	Optional			X	
SARAVENA	D-3				MW	AWOS-3	Optional				
TAME	D-4				MW	AWOS-3	Optional				
TUMACO	D-4				VSAT	AWOS-3	Optional			X	
PUERTO INIRIDA	?				?	AWOS-3	Optional			X	
EL BANCO	—				?	Optional	Optional			X	
ARARACUARA	—				?	Optional	Optional			X	
LAS GAVIOTAS NOTE 6	—				?	—	—			X	
BARRANCOMINA	—				?	Optional	Optional			X	
LA PEDRERA	—				?	Optional	Optional			X	
PUERTO LEGUIZAMO	—				?	Optional	Optional			X	
ARICA	—				?	Optional	Optional			X	
TARAPACA	—				?	—	—			Optional	
PUERTO BOLIVAR	—				?	—	—			Optional	
MIRAFLORES	—				?	—	—			Optional	

Note #1: Since the Bogota and Ipiales airports are at very high elevation, we recommend that UAEAC consider installing heaters for deicing meteorological sensors at these two airports.

Note #2: Since San Andres and Providencia are so far away from mainland Colombia to be part of the recommended National Lightning Detection Network, we suggest that Colombia consider installing a single-point, thunderstorm detection sensor as an enhancement to each of the AWOS-3 systems installed at San Andres and Providencia.

Note #3: Considering its heavy traffic, central down-town location, and frequent closures due to low ceilings and poor visibility, we recommend that Colombia consider enhancing the basic AWOS-3 system recommended for Medellin (Enrique Olaya Herrera Airport) with ceiling and visibility sensors at each end of the runway.

Note #4: The recommended lightning sensor to be installed in Villavicencio might be better located at the Apiay Air Base, just to the east of Villavicencio.

Note #5: The recommended lightning sensor to be installed in Puerto Carreño might be better located at the nearby Marandúa Air Base.

Note #6: The lightning sensor recommended for installation in Las Gaviotas might also be able to be installed at the nearby Carimagua ATC Radar site. It is not clear whether the non-controlled airport at Gaviotas is still operational or if the IDEAM radiosonde site at Las Gaviotas is still functional, so this site may be problematic.

Table 4.4 EarthSat Recommended Instrumentation and Observational Facilities for Colombian Airports (From Table A-3, Working Paper 2)

As in Technical Option 1, we also recommend providing the hardware and software for forecaster data integration workstations, preflight and local pilot briefing workstations and software templates for SIGMET and AIREPs. The primary cost difference between Technical Option 2 and Technical Option 1 is the installation of AWOS-3 instrumentation at the remaining 32 controlled airports in the country.

Technical Option 2 is expected to yield a saving of 36 observer position salaries by the end of 2014. Based on history, the equipment upgrades are expected to prevent 16 small aircraft crashes and prevent two major airline crashes during the ten-year period. These preventions would yield a savings of approximately 240 lives during the period. Productivity would increase 5% per year. Benefits due to efficiencies in aircraft operations are expected to yield 1,915,992 aircraft operations that will save on average 30 minutes. This results in much larger benefits to airlines and travelers than Technical Option 1 as shown in the Technical Option 2 spreadsheet (See Appendix B).

4.3 Technical Option 3

Technical Option 3 represents the maximum effort, most costly version program. It includes all of the recommendations made in Technical Options 1 and 2, plus, among other items, the installation of 25 lightning detectors, wind shear instruments at the three airports with the highest potential for experiencing windshear, one Doppler weather radar system and a mesoscale modeling center. These additional systems are all quite valuable and would significantly improve Colombia's aviation weather program and capabilities. The program elements of Technical Option 3 are listed below.

- Setting up a Lightning Detection Network and the Maintenance and Support of the Lightning Network
- Consultant Services (site selection)
- Doppler Weather Radar
- Maintenance & Support for Doppler Radar
- Consultant Services (radar systems and installation)
- Windshear Detection & Monitoring Systems - LLWAS, Tethersondes, Doppler Weather Radar
- Maintenance & Support for Windshear Systems
- Consultant Services (terrain induced windshear)
- Mesoscale Modeling Center
- Maintenance & Support Costs for Computer Center
- Consultant Services (model setup and support)
- Maintenance & Support Costs for Computer Center
- Consultant Services (model applications and operation)

Technical Option 3 is designed to allow UAEAC to examine the financial impact of these additional program elements on the modernization program.

Technical Option 3 is expected to yield a saving of 36 observer position salaries by the end of 2014 (the same amount as in Technical Option 2). Based on history, the equipment upgrades are expected to prevent 22 small aircraft crashes and prevent three major airline crashes during the ten-year period. These preventions would yield a savings of approximately 360 lives during the period. Productivity would increase 5% per year. Benefits due to efficiencies in aircraft operations are expected to yield 2,357,292 aircraft operations that will save on average 36 minutes. This results in larger benefits to airlines and travelers than Technical Option 2, but the benefits to costs ratio is lower than in Technical Option 2 due to the large upgrade costs to implement Technical Option 3.

EarthSat has provided the spreadsheets used to calculate the expenditures and benefits for all Technical Options for a ten-year period. These spreadsheets also contain the present value calculations assuming a .03 and a .05 discount rate. We selected these two discount rates to roughly model the current rate of inflation. See Appendix B for a list of the names of each file and the material included.

4.4 Organizational Options

After our review of the technical options showed that Technical Option 2 had the highest benefit/cost ratio, the EarthSat team proceeded to analyze Technical Option 2 implemented with five organizational options as detailed in sections 5.1 to 5.4 of the Task 3 report. These options were:

- 5.1 -- Do nothing
- 5.3 -- Outsource the program for five years (Concession Model)
- 5.4 -- Implement the program solely with UAEAC personnel
- 5.2A -- Implement following the U.S. Model
- 5.2B -- Implement following the Canadian Model

The summary table for the benefit/cost ratios for the five organizational options is shown in Table 4.5.

Option	Value	Name of File Showing Calculation
5.1 Do nothing	0	No calculation was performed
5.3 Concession Model	209	Org_Option_5.3_Benefit_Cost_Analysis_Revised
5.4 UAEAC takes over	204	Org_Option_5.4_Benefit_Cost_Analysis_Revised
5.2A Follow U.S. Model	316	Org_Option_5.2A_Benefit_Cost_Analysis_Revised
5.2B Follow Canadian Model	328	Org_Option_5.2B_Benefit_Cost_Analysis_Revised

Table 4.5 Organizational Benefit / Cost Ratio

4.4.1 Do Nothing

In this option the status quo would be maintained. Because all of the other options show a positive benefit/cost ratio, this option is not recommended. Implementing any of the other four options is better than doing nothing.

4.4.2 Outsource the Program to a Contractor for Five Years (Concession Model)

Under this option, UAEAC would issue an RFP, secure a contractor and direct the contractor to implement the program. This approach creates two major unnecessary inefficiencies. First, the contractor would have to charge an overhead rate on all services, which we estimated at 70% for this analysis. Secondly, UAEAC would have to spend money on oversight, which we estimate at $100,000 per year. Furthermore, there would be costs associated with the transfer of the program back to UAEAC at the end of the five-year period. The issue of equipment ownership is something that would have to be negotiated.

Our conclusion is that this Organizational Option is cumbersome and inefficient. The EarthSat team would not recommend implementing this option.

4.4.3 UAEAC Runs the Entire Aviation Weather Program

Assuming this option, UAEAC would take full responsibility for the Aviation weather program. This option offers the benefit of full control of the Aviation Meteorological program, but at a significant cost. Implementing this option would likely result in duplication of efforts between UAEAC and IDEAM, especially in the weather forecasting area. This results in high labor costs for both organizations, although the high labor costs are mitigated somewhat by the reduction in staff from 118 to 82. Thus, the benefit/cost ratio for this option is less than for the two following options.

4.4.4 Implement the Program Using the Organizational Guidelines of the U.S. Aviation Weather Program

Under this program option, UAEAC and IDEAM would continue to share the responsibilities, but under a different structure than currently employed. UAEAC would be responsible for all surface observations and pilot briefings. UAEAC would establish seven flight service stations to aid in pilot briefing functions. IDEAM would maintain the forecasting responsibility and be responsible for issuing all SIGMET and TAFs. This option has a large benefit/cost ratio but is slightly less beneficial than the Canadian Model Option.

4.4.5 Implement the Program Using the Organizational Guidelines of the Canadian Aviation Weather Program

Under this program option, as described in Task Report 3, all surface airport observations would stay with UAEAC and IDEAM would provide all additional services, including TAFs, SIGMETs, and AIRREPs. UAEAC would negotiate a contract with IDEAM for the services using either grants or cost recovery described in the following sections. This option provides the highest benefit/cost ratio because it efficiently uses the resources of both organizations.

EarthSat has provided the spreadsheet used to calculate the expenditures and benefits for the Organizational Options for a ten-year period. These spreadsheets are presented in separate files. These spreadsheets also contain the present value calculations assuming a .03 and a .05 discount rate. We selected these two discount rates to roughly model the current rate of inflation. See Appendix B for a list of the names of each file and the material included.

5 BENEFITS OF THE MODERNIZATION PROGRAM

The movement of air traffic in Colombia will improve in part because of modernized weather instrumentation and supporting operating systems, better systems maintenance, enhanced communications, more efficient staff assignments and increased training and education.

The EarthSat team tried to quantify the direct benefits resulting from the improved weather reporting and forecasting. This required some key assumptions. First, there was no attempt to incorporate inflation. For the purposes of these analyses, inflation was set to zero. Second, the EarthSat team assumed there were no secondary benefits. These would include such things as hotels, restaurants, roads etc, necessary to provide for increased air travel as a result of the proposed changes. Third, all analyses were performed in U.S.$. Finally, labor cost assumptions were made for certain categories of workers in the Colombian met system operation.

The EarthSat team quantified five categories of benefits:

- Automation of Observing Operations
- Increased Safety (Aircraft and Insurance)
- Improved Productivity of Staff
- Efficiency of Aircraft Operations
- Time savings for Travelers

Benefit Input	Value	Source
Salary Observer	$12,000	UAEAC, Meeting Discussions, 2/08/06
Salary Meteorologist	$11,500	UAEAC, Meeting Discussions, 2/08/06
Salary Met Director	$30,000	UAEAC, Meeting Discussions, 2/08/06
Salary Met Supervisors	$12,000	UAEAC, Meeting Discussions, 2/08/06
Average Value Small Aircraft	$2,000,000	UAEAC, Meeting Discussions, 2/08/06
Average Value Civilian Aircraft	$149,000,000	http://www.boeing.com/commercial/prices/
Average Value Human Life	$3,000,000	http://www.dailyprincetonian.com/archives/2002/10/09/news/5646/shtml http://econoclectic.powerblogs.com/posts/1131471000.shtml
Average Value Flight Hour	$3,030	*Standard Inputs for EUROCONTROL Cost Benefit Analyses, 2005 Edition*, European Organisation for the Safety of Air Navigation, February 2005, EATMP Infocentre Reference, 020717-02
Average Value of time for traveler	$35	*Economic Values for FAA Investment and Regulatory Decisions, A Guide*, GRA Incorporated with the Aviation Specialists Group Incorporated, December 31, 2004, Contract Number DTFA 01-02-C00200
Average Passenger Load per Flight	80	UAEAC, Meeting Discussions, 2/08/06

Table 5.1 Benefit Input Table Costs

5.1 The benefits resulting from Automation of Observing Systems

The benefits resulting from using the new equipment includes more confidence in weather data interpretation and enhanced weather briefings for pilots and dispatchers, particularly with the use of graphical weather products. In addition to the airlines, pilots, and dispatchers, improvements in meteorological services will also provide critical operational information for UAEAC's air traffic control staff. The benefits resulting from equipment operation itself include more efficient operation of the instruments, less maintenance and calibration and longer instrument life cycles. Automated systems will provide around-the-clock observations with fewer trained observers, while using existing staff to put a new emphasis on maintenance, forecasting and both pre-flight and in-flight briefing. Eventually over a ten-year period automation is expected to lead to significantly fewer staff being needed to perform the necessary tasks. The formula used to calculate this improvement was:

(Number of personnel eliminated x annual salary of the eliminated position.)

5.2 Benefits resulting from improved safety

Data from the U.S. National Transportation Safety Board indicate that weather is a factor in nearly 23% of all accidents. The benefit of improved weather instrumentation is that it can play a role in preventing aircraft damage or loss.

Colombia's air safety will be improved by the adoption of any one of the recommended actions in this report. Over the past five years, Colombia has had 29 accidents with 184 fatalities. Weather factors, such as fog lowering visibility were often the cause of the accidents. In this study, this benefit was calculated by the following formula:

(Number of small aircraft saved x the value of a small aircraft + number of large civilian aircraft x value of large aircraft + number of lives saved x value of a human life.)

5.3 Improved productivity of staff due to technical improvements and organizational changes

Training enables weather staff to do their jobs more efficiently. Training can also be used to develop advanced capabilities in specialized applications such as radar meteorology, satellite meteorology and numerical modeling. The benefit of this advanced training is that it will introduce new capabilities enabling UAEAC and IDEAM staff to report on and forecast the weather in their respective areas more effectively.

More efficient staffing will eliminate parallel systems with considerable duplication of components and overlapping responsibilities. The current system seems to encourage split obligations and affiliations. IDEAM observers, for example, tend to use IDEAM measurements systems to generate METARs rather than the better positioned UAEAC sensors near the runway. The formula used to calculate this benefit was:

(Number of employees x productivity improvement x average salary of employees)

5.4 Benefits from increased efficiency of aircraft operations

The mountainous terrain of Colombia, the periods of low visibility and other poor weather conditions cause many diversions of aircraft from their original destination. This is especially true in Latisha and San Andreas, where anecdotal evidence suggest plane often take off from their origination, reach the destination and have to turn back to their origination.

Accurate METARS and TAFs can prevent planes from leaving for a destination that might develop or be experiencing hazardous weather conditions. They can also prevent an aircraft already en route from flying in to such conditions. A delay in the flight or a deviation to a safe alternate, though costly, is certainly preferable to flying into a dangerous weather situation.

The benefits to aircraft operators are in savings in fuel costs, aircrew time costs, ground crew time costs, and fewer maintenance costs due to weather delays or weather damage. The formula the EarthSat team used to derive this benefit was:

(Number of aircraft operations affected by weather x flight hours wasted x dollar value of a flight hour)

5.5 Benefits to travelers – time saving for travelers

Travelers gain indirect cost savings due to more efficient use of work time, and a reduction of out-of-office time and hotel expenses for personnel. Determining these benefits is difficult, but a general formula below is used to quantify these savings.

Value of passenger time savings = (flight hours saved) x (average passenger load per flight) x (value of passenger time per hour)

6 ENVIRONMENTAL REPORT

The Statement of Work for this upgrade program states that the project requires a corresponding environmental overview study covering the following topics (procedures):

- Selection and substantiation of the methodology for developing the study
- The environmental diagnostic
- Identification of the liaison between the project and the environment
- Dimensioning the project impact on the environment and vice-versa
- Elaboration and recommendation of mitigation and corrective measures

The topics listed above lead EarthSat to believe that Colombia wants to assess the impact of the modernization using environmental assessment procedures that are similar to the steps the U.S. takes to assess the environmental implications of proposals for legislation, and other major government actions that might significantly affect the quality of the human environment. Upgrading the Colombian Aeronautical Meteorological System is a major government program lasting ten years or more and involving two major government organizations that conduct operations throughout Colombia. The environmental assessment process provides a systematic way of evaluating the overall effects of the program as a whole, and the relative impacts of each of the major parts of the program, since some actions or procedures will have more impact than others.

Much of the modernization program involves updating software, workstations and display systems, upgrading communications, training observers, briefers and forecasters, increasing the effectiveness of the MET staff, and considering organizational change within and between UAEAC and IDEAM staff. These are activities that will have economic and social impacts on the modernization program. However, there are actions that might cause more physical impacts on the environment, such as constructing, modifying and updating weather observation instrumentation, building Doppler radars and their associated structures, upgrading power supplies, and constructing new buildings for office space, if necessary. Without more detailed information about Colombia's environment, we cannot do an environmental assessment. However, we can provide a general idea of how the magnitude of potential impacts is determined, reported on, and mitigated based on examples of similar projects here in the United States.

In the following sections we briefly describe Colombia's environmental setting and some of the country's major environmental issues, then we describe in general Colombia's environmental assessment process and provide our overview of potential impacts by scenario.

6.1 Colombia's Environmental Setting and Issues

Colombia has a population of 42,954,279 and an area of 1,138,910 sq. km. It is the second most populated country in South America, and the fourth largest in area. Colombia has a wide range of environments and one of the greatest varieties of wildlife and plant species in the world. Major environmental issues include deforestation, soil and water quality damage from overuse of pesticides and mining, and air pollution from vehicle emissions, especially in Bogotá. Colombia has 34 national parks, 12 state-run nature reserves and 120 privately owned and administered nature reserves. The combined area of the national parks and state-run reserves constitutes 8.1% of the country's territory.

Environmental agreements in which Colombia is involved include: the Antarctic Treaty, Biodiversity, Climate Change, Climate Change-Kyoto Protocol, Desertification, Endangered Species, Hazardous Wastes, Marine Life Conservation, Ozone Layer Protection, Ship Pollution, Tropical Timber 83, Tropical Timber 94, and Wetlands. It has signed, but not ratified, the Law of the Sea Convention. Colombia has ratified the convention of 1991 of the International Labour Organisation (ILO) concerning Indigenous and Tribal People. There are some 80 groups of indigenous people in Colombia. According to Caritas Europe, their native communities are organized in councils governing in accordance to their own customs: land use, economic and social development, protection of natural resources, tax collection, and peace keeping.

Colombia is the only country in South America with coasts on both the Pacific Ocean and the Caribbean Sea. The Pacific coast has widespread and ecologically important mangrove forests along its shoreline. From the shore and up the western mountain slopes, the land cover transitions from rain forests to dry forests, to the montane forests of Bogotá, and eventually to the high alpine grasslands, bogs and open meadows of the northern Andes, where many peaks exceed 5,000 meters in elevation. Pico Christobal Colon is the highest point in Colombia at 5,775 meters. The Caribbean coast supports mangroves along the sea with a dry scrub vegetation cover dominating the landscape inland before the terrain rises to the central highlands and Andes Mountains.

The eastern half of Colombia, with the exception of the Chiribiquitte Highlands and some adjacent hills, is in an extensive plain. The northeastern plain is in the dry Llanos savannas grassland ecoregion. Moving southward, the plain becomes moist forest, rain forest in the central eastern plain, and then flooded rain forest in the southern part of the plain.

Although it is important to ensure sound development in all of Colombia's environments, the area known as the Northeast Andes Regional Complex (NAEC) is experiencing some of the most intense impacts because of rapid population growth, urban sprawl, mining and other activities that threaten this environment. In general, the region has the highest population density and correspondingly, more of Colombia's airports.

6.2 Colombia's Environmental Program

Colombia was the first country in South America to develop a program for responding to environmental issues by issuing Law 2811/1974, 'Code for the Renewable Natural Resources and Environmental Protection' in 1974. The new law created many innovative statutes and procedures for monitoring the environment, but the agency with program oversight at the time was somewhat limited in its ability to cover a wide range of environmental issues. In 1993, through Law 99, Colombia created the Ministry of Environment (MoE) as an independent office having the authority to affect and determine policies at the *national level.* The Ministry also administers the national parks, and among the organizations operating under the ministry is

IDEAM. The Ministry has developed environmental guidelines designed to promote the best practices of environmental management for the mining industry, the electrical industry, oil and gas, transportation, and urban development.

During the 1950s, Colombia organized its first "Regional Autonomous Corporation," which was essentially a development organization for a particular region. Autonomous Regional Corporations were created and made responsible for the implementation of environmental policy at the *regional and local levels.* Law 99 played a part in restructuring and creating new Autonomous Regional Corporations, and Colombia now has over 30 of these corporations, and has designated them as the country's main environmental authorities. Implementing policy from these regions enables people to take action appropriate to the physical, cultural, and economic conditions specific to each of the regional corporations.

6.3 Determining the environmental impact of an action

Over the years, the environmental assessment process in the U.S. and in other countries has grown into a comprehensive and often complex procedure supported by laws, statutes and methodologies that ensure assessments are conducted thoroughly and completely. In general, our assessment procedures in the U.S. fall into one of three categories as part of a three-step process used to determine whether it is necessary to prepare an Environmental Impact Statement (EIS). They are: 1) determining environmental exemptions or categorical exclusions, 2) preparing an environmental assessment (EA), or 3) preparing an environmental impact statement per se.

1. Categorical exclusions. Actions that do not individually or cumulatively have a *significant* effect on the environment are usually found on a list of *categorical exclusions* for a particular type of project. If the action is exempt or categorically excluded, there is no need to move further into the environmental review process and a report is prepared stating this. AWOS, RVR and LLWAS are examples of instrument systems that are often, but not always categorically, excluded.

2. Environmental Assessment. If the action is not exempted or categorically excluded, then an Environmental Assessment (EA) is prepared. An environmental assessment is a concise public document an agency prepares when a project is not covered by a categorical exclusion, and the lead agency does not know whether the impacts will be significant. When completed, the EA determines whether there is 1) a finding of no significant impact (FONSI), or 2) that there are potentially serious impacts requiring a comprehensive environmental impact statement. Examples of actions that might require an EA include constructing a major runway extension, the establishment or relocation of an instrument landing system or an approach lighting system, or the construction of a large building or facility.

3. Environmental Impact Statement (EIS). The EIS is the most detailed and comprehensive of our environmental reviews. An example of an action requiring an EIS is the first time airport layout plan approval or airport location approval for a commercial service airport located in a standard metropolitan statistical area. The contents of an EIS are listed under

the description of the EIA used by Colombia on for their Category 3 Projects as described below.

Colombia has a similar system to ours that appears to be based on a United Nations Environmental Program (UNEP) environmental assessment model. UNEP and Colombia call their environmental documents Environmental Impact Assessments (EIA). As with our definition of "human environment," which includes the natural and physical environment and the relationship of people to these environments, the UNEP resource manual states that EIAs must integrate social, economic and biophysical impacts to the maximum extent possible. The UNEP model's selection of which level of assessment to perform is based on three categories of effort termed Category 1, 2 or 3 projects, respectively, which closely parallel our procedure.

Category 1 projects do not require any further environmental study beyond the work done to make the initial decision. This appears to correspond to our determining categorical exclusions.

Category 2 projects can be subject to a limited EIA. Basically, for such projects the range of environmental issues needing attention is relatively narrow, and their nature/scope can be evaluated without great difficulty. This seems to equate our environmental assessment step.

Category 3 projects require a comprehensive EIA, equivalent to our EIS. Such a judgment is based on the strong likelihood that a proposed project will result in a range of significant adverse impacts, which need detailed investigation and subsequent evaluation. Furthermore, it is likely that specific measures will be needed to ensure that, if the project is implemented, minimum environmental damage will result. A UNEP environmental impact assessment report should contain:

- A description of the aims of the project;
- A discussion of relationship between the proposed project and current land-use and other relevant policies for the area likely to be affected;
- A description of the proposed project and alternatives (including no development). This should be brief and attention should be paid to the major differences between the alternatives;
- A description of the expected environmental conditions at the time of probable project implementation (biophysical, socio-economic etc);
- A relationship between short term uses of the environment versus long term productivity;
- A discussion of irreversible or irretrievable commitment of resources;
- An evaluation of the impacts of each alternative, with clear information on the criteria used to assign significance (also, descriptions of the characteristics of each impact);
- A comparative evaluation of alternatives, covering significant adverse and beneficial impacts, mitigation and monitoring measures and identification of the environmentally preferred option if possible using a set of sustainability criteria;
- An impact management plan; and
- A discussion of uncertainties involved in interpreting/using results from predictive methods and analytical techniques and description of gaps in baseline and other data used in the EIA work and included in the EIA report.

Colombia has an additional step in its environmental impact process where a petition for an *environmental license* is required before proceeding with projects or activities that might cause severe damage to the environment or landscape. The environmental license is granted by a legal statement that specifies how the project must be developed to ensure proper environmental management. The Ministry of Environment and the Regional Corporations have lists showing activities that require an environmental license. The MoE list shows that the construction for the installation, amplification or upgrading of international airports requires a license. At the Regional Corporation level, a license is needed for the construction, amplification, adaptation or operation of national airports, both public and private, and of air fumigation terminals. Note that these are general statements as to the effects of airport projects and most likely refer to activities we used as examples of actions needing an EA or EIS. Some elements of airport development, such as installing an AWOS might have no adverse impacts at all, while installing NEXRAD units or radar networks have required EISs in the United States.

6.4 Determining probable environmental effects of the modernization project

As stated in the introductory paragraphs of this section of the report, many of the modernization activities will have economic and social impacts. Others, such as constructing, modifying and updating weather observation instrumentation, building Doppler radars and their associated structures, upgrading power supplies and constructing new buildings for office will have physical impacts on the environment. Some of these impacts might be direct effects caused by the action at the same time and place. Other actions might have indirect affects that might occur at a later time or are further removed in distance, but must be foreseeable. Yet others may be cumulative and result from incremental impacts of the action when added to other past, present and foreseeable future actions.

Beginning with a Category 1 level approach, the Colombians can determine which of the meteorological systems when built new or upgraded will require further environmental study. Many of the weather observation instruments or systems proposed for placement or modification in Colombia are found under the U.S. FAA categorical exclusion class. Categorical exclusions represent actions that the FAA has found, based on past experience with similar actions, do not normally require an EA or EIS because they do not individually or cumulatively have a significant effect on the human environment. Generally, AWOS, LLWAS, RVRs and many other kinds of airport instrumentation are listed as categorical exclusions. However, there might be *extraordinary circumstances* where these instrument arrays might have impacts on particular environments, landscapes, wildlife populations, historical areas and communities that invalidate them from being considered categorical exclusions. Examples of such extraordinary circumstances relating to specific types of instrumentation along with other potential impacts of various types of meteorological equipment are discussed in the next sections.

The list of potential impacts below is a form of checklist to be referred to when determining when there might be extraordinary circumstances associated with categorically excluded items. We left in the list references to the various U.S environmental and historic Acts, Native American tribal issues and actions taken at National, and state and local levels. We assume they will be comparable to Colombia's environmental or land use acts, statutes pertaining to indigenous peoples and issues addressed by the Ministry of the Environment or the Regional Corporations.

Extraordinary circumstances exist if the equipment, activities or procedures:

a. Have an adverse effect on cultural resources protected under the National Historic Preservation Act of 1966, as amended.

b. Might occupy a historic site.

c. Have an impact on natural, ecological or scenic resources of Federal, Tribal, State, or local significance (for example: Federally listed or proposed endangered, threatened, or candidate species or designated or proposed critical habitat under the Endangered Species Act), resources protected by the Fish and Wildlife Coordination Act; wetlands; floodplains; prime, unique, State or locally important farmlands; energy supply and natural resources; and wild and scenic rivers, including study or eligible river segments and solid waste management.

d. Cause a division or disruption of an established community, or a disruption of orderly, planned development, or an inconsistency with plans or goals that have been adopted by the community in which the project is located.

e. Cause an increase in congestion from surface transportation (by causing decrease in Level of Service below acceptable level determined by appropriate transportation agency, such as a highway agency).

f. Have an impact on noise levels in noise-sensitive areas.

g. Have an impact on air quality or violate local, State, Tribal, or Federal air quality standards under the Clean Air Act Amendments of 1990.

h. Have an impact on water quality, sole source aquifers, a public water supply system, or State or Tribal water quality standards established under the Clean Water Act and the Safe Drinking Water Act.

i. Cause disruptive relocations or relocation where there is inadequate housing or living resources.

j. Have effects on the quality of the human environment that are likely to be highly controversial on environmental grounds. The term "controversial" means a substantial dispute exists as to the size, nature, or effect of a proposed Federal action. The effects of an action are considered highly controversial when reasonable disagreement exists over the project's risks of causing environmental harm. Opposition on environmental grounds by a Federal, State, or local government agency or by a tribe or by a substantial number of the persons affected by the action should be considered in determining whether or not reasonable disagreement regarding the effects of a proposed action exists.

k. Have the likelihood to be inconsistent with any Federal, State, Tribal, or local law relating to the environmental aspects of the proposed action.

l. Are likely to directly, indirectly, or cumulatively create a significant impact on the human environment, including, but not limited to, actions likely to cause a significant lighting impact on residential areas or commercial use of business properties, likely to cause a significant impact on the visual nature of surrounding land uses, likely to be contaminated with hazardous materials or likely to cause such contamination.

6.5 Examples of potential environmental impacts associated with modifying and updating the weather observation instrumentation

In the following paragraphs we look at the potential environmental impacts of the different weather instrumentation in use or proposed for the modernization. The instrumentation considered for purchase, modification or discontinuation includes:

MET Gardens discontinuation
AWOS instrumentation suites (possible maximum 48 - at all controlled airports)
RVR sand ceilometers
Radiosonde instruments
LLWAS windshear detection systems and extended anemometer networks
Tethersondes
Lightning detectors - 25-32 systems.)
Weather radars – Initially one installation, potentially 10 to 15 systems
GOES receiving stations. (The recommended additional systems have already been purchased.)
Web cameras

6.5.1 MET Gardens, AWOS, RVRs, ceilometers, and web cameras

AWOS stations, RVRs, ceilometers, and web cameras, because of their size and location on the airport, most likely will have little visual, air quality or noise impact. Unless the airport itself is located in an environmentally sensitive area, they probably will not threaten endangered species and will fit in to the local land use and most likely won't affect any historical or cultural resources. Their energy requirements are not great and their social impacts are nil. Building those causes only a temporary disturbance with no lasting effects.

Normally these instrument arrays are listed under categorical exclusions in the U.S. However, there are some exceptions. Engineers had to redesign a new instrument landing system (ILS) maintenance path at the Montgomery, Alabama Airport to reduce potential impacts on sensitive vernal pools that were a shrimp habitat.

6.5.2 Radiosondes

The units consist of the receiving station, tracking antennas and the balloons carrying the sonde. Colombia has five radiosonde sites, three of which are operational. Four are located on airports and one is not. Some radiosonde unit receiving stations are housed in small buildings, which in principle should not have major impacts on the environment.

6.5.3 *LLWAS*

LLWAS systems can have wind sensors mounted on poles sometimes as high as 150 feet and located 2000 to 3500 feet but not more than 5000 feet from the centerline of the runway (Whatley ARS website). Some LLWAS systems require an extensive network of anemometers with strict positioning requirements surrounding the airport out to two or three miles from the end of the runway.

Much of Colombia's wind shear problems are terrain induced. Major LLWAS installations might not be appropriate in this situation. One option that may be appropriate for Colombian airports with windshear and turbulence problems would be to install an extended network of anemometers along the runway and at critical terrain features surrounding the airport. While not a true LLWAS system, the anemometers can help monitor the surface wind environment around and near the airport.

LLWAS systems are included in the FAA list of categorical exclusions. However, depending on the size of the airport and location of the sensors, LLWASs in Colombia might be evaluated against items on the extraordinary circumstances for conflicts with land use, visual issues and environmental issues. For example, the U.S. Western Pacific Region FAA selected an alternative site location for an LLWAS station to avoid potential impacts to the endangered giant garter snake. If avoidance were not possible, the FAA Region would attempt to mitigate the impact as much as possible. Anemometers mounted off the airport in the surrounding terrain might engender land use conflicts and possibly visual problems, but their impacts would probably be minor.

6.5.4 *Lightning detectors*

Lightning detectors use a network of detectors, usually mounted on poles or on top of existing buildings, which pinpoint cloud to cloud and cloud to ground lightning strikes and relay the raw strike information to a central processing facility. The strike information is processed, archived and displayed on video screen at the center and can be sent other centers on the network.

The introduction of a national network of lightning detection systems will require a control room for monitoring the system and for generating operational products. This control room should not have to be very large (perhaps 10-15 m^2), but will need to have good access to a variety of communication links and be equipped with backup power and UPS. These central processing and product generation workstations could also be located within an expanded Colombian Aeronautical Meteorology Forecast Center.

6.5.5 *Weather radars*

Terminal Doppler Weather Radars (TDWRs) and Next Generation Radars (NEXRADs) are housed in buildings and have large radomes containing the radar units. The radar proposed for Colombia will require a small to moderate-sized building to house the radar electronics and control equipment, and to serve as a local maintenance and control center. In most cases the building would be adjacent to the tower and radome that would house the radar's antenna. The radar will need to be served by a high-speed data line, such as a dedicated T-1 line, for transmitting the beam-by-beam radar imagery to UAEAC and IDEAM meteorological centers. Areas nearby the radar site may need to be controlled to limit future construction (see Section 4.7 in Working Paper Number 2). The minimum space requirements would be of order 100 m^2 with a backup power system and UPS.

In some cases, environmental assessments found they caused no significant impact, in other cases adverse environmental effects have included community disruption, environmental controversy, impacts on the natural environment and the cumulative impacts of all the proposed systems together. Issues related to community disruption and environmental controversy include health concerns about exposure to the pulsed beams of radio frequency radiation that the radar systems would emit, locating radars too close to homes in communities and the radar beams disrupting the operations of an astronomical observatory. According to a draft Environmental Impact Survey (EIS) done by FAA engineers, an optimal site for the Doppler radar should have a clear line-of-site and provide coverage from 70,000 feet down to 300 feet.

Environmental concerns include worries about sites built in or near the habitats of endangered species, birds striking the domes or being affected by the radar beams as they fly through them (only a factor for very high power radar systems), the visual impact of the structures, access roads to the sites causing environmental damage and the site causing some disruption in ground water recharge. Mitigation of the visual effect on one of the sites was done by coloring the tower dark green, while wildlife biologists stated that there would be no bird strikes at another site because the towers were not that high and were highly visible in their original color. However, the Alaskan Region planned a secondary surveillance radar project around nesting eagles and a radar site in New York had to be built in a site other than the planned site to satisfy community reaction to the radar.

6.5.6 Affects of increased traffic into airports with upgraded facilities

It is possible that improved observation systems and improved flight services might result in enough new traffic to cause increases in noise and air pollution, depending on the location of the airport. Improvements of ILS systems in the U.S. leading to increased air traffic have required environmental actions to mitigate the effects of noise and degraded air quality. Other indirect affects might include impacts on the economy or infrastructure of the airport town or city because of increased transient or permanent population change.

6.5.7 Updating software and weather workstations and display systems

These activities probably will not cause environmental impacts. Most of the upgrades will most likely occur within exiting systems and will be economic and addressed in the cost benefit scenarios.

6.5.8 Upgrading communications

The communications upgrades probably will not cause significant impacts unless microwave towers or other large facilities are needed.

6.5.9 Training observers, briefers, and forecasters

Training staff at their workplaces or at other sites and institutions should not cause environmental impacts.

6.5.10 Providing office space for staff and for equipment

Much of the new office space might be found in existing installations. If new buildings need to be erected, then certain steps might be considered in their building design and placement. Building construction and operation can have direct and indirect an impacts on the environment. Figure 6.1 shows the kinds of environmental impacts generally associated with buildings as reported by National Institute of Building Sciences.

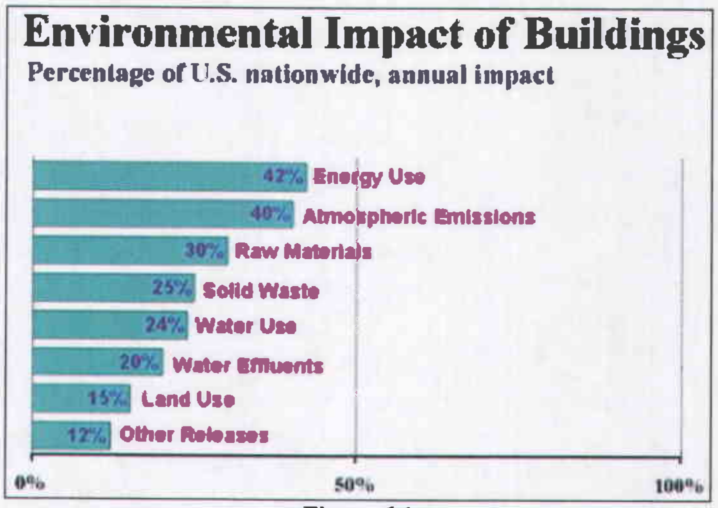


Figure 6.1

The Institute states that although building design is constantly changing, there are six fundamental principles of building construction and design that nearly everyone agrees on, and these are to:

- Optimize site potential
- Minimize energy consumption
- Protect and conserve water
- Use environmentally preferable products
- Enhance indoor environmental quality
- Optimize operational and maintenance practices

6.5.11 Agency reorganization

Unless agency reorganization leads to the construction of facilities that cause physical impacts, the major impacts will probably be more socio-economic in nature. They can include disruption in daily living patterns, disruption of social networks, changes in distribution of power and authority, disruption in social networks and economic inequities among other things.

6.6 Environmental Overview by Option

6.6.1 Option 1

Option 1 proposes upgrading the AWOS-3, upgrading the radiosonde network, placing Web cams at 16 controlled airports and adding RVR and ceilometers systems to selected ILS and airports with higher numbers of daily flights. In general these weather observation systems pose no major environmental threats unless there are some environmental circumstances in particular environments that warrant further evaluation as referred to in the examples above. No lightning detectors or larger observational systems like weather radars that might have a potential for some adverse environmental effects, are proposed for deployment in this option.

Modifying the software and weather workstations and display systems, upgrading communications, training observers, briefers and forecasters and enhancing their ability to prepare METARs and TAFs should have no impact on the environment.

6.6.2 Option 2

Option 2 proposes upgrading all 48 controlled airports to the AWOS-3 sensors, upgrading the radionsonde network, placing Web cams and providing TAF capability on the remaining airports. As in Option 1, no larger observational systems like weather radars, which might have a potential for some adverse environmental effects, are proposed for deployment in this option. Modifying the software and weather workstations and display systems, upgrading communications, training observers, briefers and forecasters and enhancing their ability to prepare METARs and TAFs should have no impact on the environment.

6.6.3 Option 3

Option 3 proposes all of the upgrades included in Options 1 and 2, as well as some additional large-scale items. In this option we suggest AWOS-3 at all controlled airports, 25 to 32 lightning detectors at sites countrywide, and a single Doppler radar to be installed in Bogotá. We can assume that the AWOS systems, as stated above, with some possible exceptions, will cause no significant environmental disruptions. The radar sites and lightning detectors should be evaluated individually and for the cumulative affects on the environment of all of the systems.

6.7 Potential for Use of Solar Power for Meteorological Equipment

Many meteorological systems can be powered by solar power. Specific instruments available in solar configurations will vary with the Vendor, but in general the main exception to compatibility with solar power would be ceilometers and some RVR systems (transmissometer based systems).

Airports with ILS systems would have to have line power for the ILS systems. ILS airports ceilometers are the main instrument at issue. Because ceiling and visibility are basic weather factors affecting airport operations we recommend that all controlled airports have these instruments. The ceilometer as a basic component of an airport weather station (e.g. for METARs) doesn't have to be out by the runway threshold or mid-field, but can be installed wherever it is convenient (meaning where power is available).

Line power is a problem at many Colombian airports. There were no conduits for power and data cables installed under the runways and generally around the airport site when the airports were built (or in subsequent upgrades). Because computers that are used as part of the AWOS systems are not generally run on solar power, the real issue is digging a trench for a power cable.

We recommend that, as a general long-term goal, Colombia should upgrade all their controlled airports to have reliable electrical power (including backup generators for essential systems, as required) and high-speed (broadband) data communication links. Colombia should not be forced to use solar power at controlled airports because line power isn't available or reliable, or have airports that can't communicate (both voice and digital data) with the rest of the national aviation system. Although it is rare in Colombia, any airports where ice is a problem would require line power for instrument heaters. We recommend that UAEAC examine the need for instrument heaters at two airports, Bogota and Ipiales (both located at high altitudes). Potential solar installations should be first be evaluated for climatological hours of sunlight. Some mountain sites may be problematic. Similarly, airports that experience high winds (such as San Andres with the recent hurricane) may have problems with the solar panels being subject to wind damage. Line power, on the other hand, would have to be evaluated on the basis of its reliability and frequency of outages (both currently and after any planned national power system upgrades).

In summary, we recommend that Aero Civil install solar power systems for instruments at many airports where it is practical but we believe it is essential for reliable operations that a plan be developed for future upgrades to line power (with backup generators).

7 Cost Recovery Analysis

7.1 Introduction

As the designated Meteorological Authority for Colombia, UAEAC is responsible for the provision of aeronautical meteorological services that meet the international standards and recommended practices found in ICAO Annex 3. EarthSat recommends that UAEAC implement a cost recovery program to provide the revenue to sustain and evolve the modernization. In this section of Working Paper 4, EarthSat will discuss the cost recovery plan for the ongoing costs of Technical Option 2 implemented following the Canadian Model. It is important to note that as the designated Meteorological Authority in Colombia, UAEAC is the only agency that can recover costs for the aeronautical meteorological modernization directly from aviation interests.

7.2 Background

In 2003, the World Meteorological Organization (WMO) performed a survey of its members to determine the extent and methods of cost recovery for aeronautical services among its members. The results of the survey show that 59% of the countries responding recover costs for providing meteorological services to aviation. In addition, 55% of the remaining countries that were not currently recovering their costs were planning to do so in the future. WMO and ICAO have worked very closely to assist countries with the implementation of cost recovery systems. For example, in its long-term plan for the period 2004-2007, the WMO pledged to provide guidance and assistance to "members undergoing review of their national arrangements for aeronautical meteorological service delivery including the implementation of cost recovery." As part of this effort, the WMO has held various workshops and seminars. A presentation at one such seminar described the operational and design principles of a cost recovery program. The primary message of this presentation is that "well designed cost recovery arrangements can improve economic efficiency and promote equity by raising cost consciousness and awareness among the National Meteorological Services and the users.[1]" The full set of operational and design principles from this presentation are summarized below.

1. Set charges to recover the additional costs of incremental products or services where it is cost effective to do so. The charges should reflect the costs of providing the product or service and should generally be imposed on a fee-for-service basis.
2. Costs that are not directly related or integral to the provision of products or services should not be recovered.
3. Cost recovery is inappropriate where the products and services have a high degree of "public good" characteristics or where there are significant positive benefits for other user communities.
4. Governments should not require the agency to recover a specific proportion of their total budget from the users. "Over recovery" whereby an agency is required to recover more than the cost of a particular activity in order to fund other unrelated Government commitments is particularly inappropriate.

[1] *Cost Recovery by National Meteorological Services: the Rationale, Application and Implications*, Don Gunasekera, Bureau of Meteorology, Austrialia, WMO Seminar on Cost Recovery and Administration for RA V, Vava'u Tonga, 1-5 December 2003

5. Any substantial cost recovery arrangement should be undertaken only after appropriate user/stakeholder consultation.

EarthSat has followed these principles to design a cost recovery plan for UAEAC. We have obtained additional guidance from WMO Document 904 – Guide on Aeronautical Meteorological Services Cost Recovery and ICAO Document 9161 – Manual on Air Navigation Services Economics.

7.3 Cost Recovery Plan Design

EarthSat created the process shown in Figure 7.1 to develop the cost recovery plan for UAEAC.

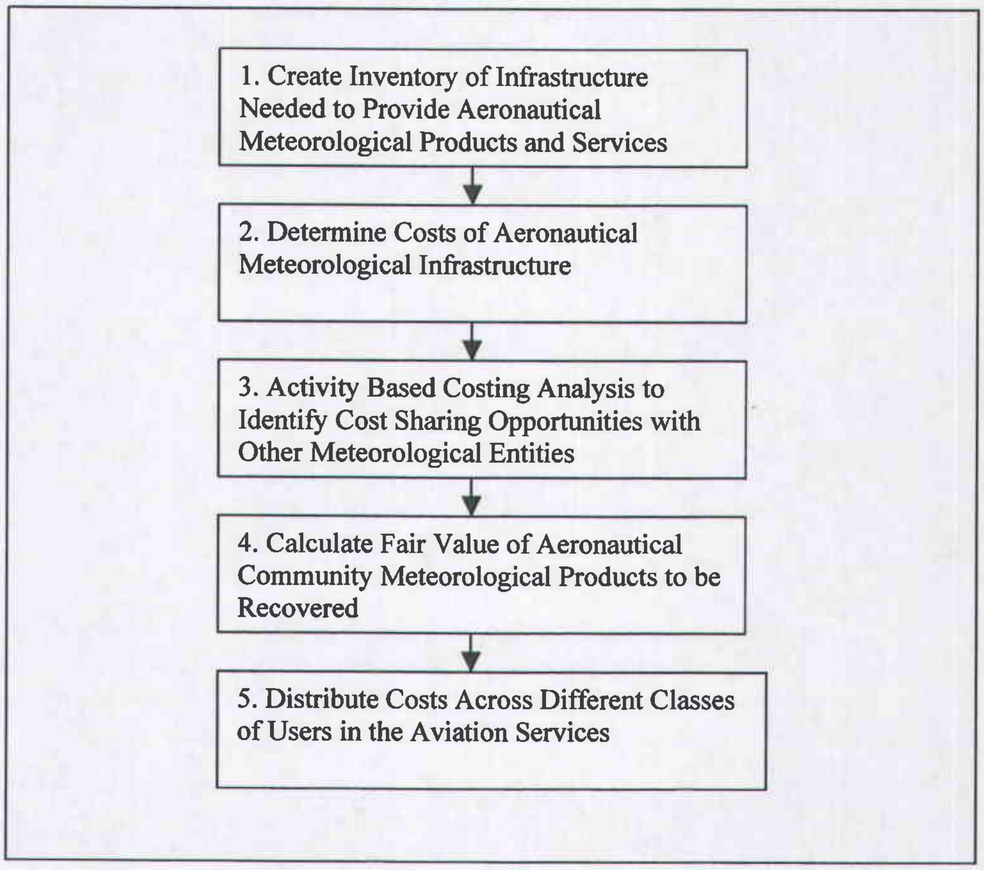


Figure 7.1: EarthSat Cost Recovery Development Process

Our process includes the following assumptions:

1. The modernized Aeronautical Meteorological Program will be administered by UAEAC following the Canadian model as described in Section 5.2 per EarthSat's recommendation in Working Paper 3.
2. A cash generating fee-for-service plan will be implemented to recover the costs of the upgraded program. UAEAC will implement a mechanism that will retain all the user fees collected in support of the Aeronautical Meteorology Program.
3. Any surplus funds generated from the cost recovery will be used to add some of the recommended options proposed in Technical Option 3.

The previous sections of this report describe the Step 1 inventory and Step 2 costs of the infrastructure for upgrading the Colombian Meteorological Program. **The total cost of all basic recommended items following the Canadian Organization Model over the ten-year period is $18,919,000 (U.S.) for the 10 years of the project.**

7.3.1 Activity Based Costing Analysis (Step 3)

The aviation community rightfully demands that the fees they are charged for weather information only support the infrastructure needed to create the products they use. To address this concern, UAEAC must identify any ongoing costs of the modernization that are not aviation related or have uses outside of the aviation community. To perform this identification process, EarthSat put the equipment of all the options into one of three categories as shown in Table 7.1.

Exclusively Used by Aviation	Used by Aviation and Others (Mixed Use)	Not Used by Aviation
Basic Control Tower Met Systems	Lightning Detection Network	
RVR and Ceilometers for ILS Runways	Doppler Weather Radar	
Comprehensive AWOS Replacement Systems	Mesoscale Modeling Center	
Airport Met Networking Upgrades	Radiosonde program	
Forecast Data Integration Workstation	METARs and a national network of AWOS-3 systems.	
Software Templates for AIREP and SIGMET	Airport web cameras.	
Pre-flight (Pilot) Briefing System & Software		
Communications Upgrades (MET data distribution)		
Weather Systems for Training and Calibration		
Airport Web Cameras		
Windshear Detection & Monitoring Systems		

Table 7.1: Classification of Modernization Equipment

The next step therefore, is to determine what proportion of the mixed-use items should be allocated to aviation. WMO Document 904 recommends five different potential methods or a combination of those methods to perform this calculation. Sharon S.Y. Lau of the Hong Kong Observatory summarizes those methods as follows:

1. In proportion to the estimated aeronautical, and non-aeronautical use made of the core service,
2. In proportion to the estimated time used by computers for aeronautical and non-aeronautical purposes,
3. In proportion to the volume of the information transmitted for aeronautical and non-aeronautical purposes,
4. In proportion to the number of personnel working on aeronautical and non-aeronautical purposes,
5. On the basis of results from an analytical accounting system which ensures an equitable allocation of the costs.[2]

EarthSat's application of these methods for each mixed-use item is presented in Table 7.2 and is discussed below. Note that except for the Radiosondes and communication upgrades, the remainder of the basic upgrades are in the optional recommendations in Technical Option 3. Also note that the Wind Shear System is not discussed because the option use is assigned 100% to UAEAC.

System Component	Total Cost	IDEAM Contribution	UAEAC Contribution	FAC Contribution	Other Contribution
Radiosonde Network	$3,590,000	33%	33%	33%	
Wind Shear Detection	$1,672,000		100%		
Lightning Network	$5,032,000		75%		25%
Doppler Weather Radar	$5,033,000	33%	33%	33%	
Mesoscale Modeling Center	$6,137,000	33%	33%	33%	

Table 7.2: Cost Distribution for Mixed Use Components

7.3.1.1 Radiosonde Network

Radiosondes are critical to improve the quality of almost all of meteorological products produced in Colombia. In the recommend organizational configuration, IDEAM operates the radiosonde network, and FAC and UAEAC are the primary users. To determine the portion of the funding UAEAC must provide, EarthSat used the method of estimating the aeronautical and non-aeronautical use of the radiosonde network. In this case we also differentiated between the civilian and military aviation usage of the radiosondes. Given the widespread usage of the radiosonde data, EarthSat recommends that its costs be split evenly between IDEAM, UAEAC and FAC.

[2] *Cost Recovery in Aviation Weather Service and How It Works in Hong Kong,* Sharon S.Y. Lau, Second Regional Seminar on Cost Recovery and Administration in Regional Association II (ASIA), Hong Kong, China, 4-6 December 2004

7.3.1.2 Lightning Detection Network

The amount of mixed use of the lightning detection network is difficult to quantify because creating the network through a multi-agency cooperative agreement could make it difficult to achieve the central collection and processing UAEAC needs to improve the quality of the SIGMETS, TAFS, and other aviation weather forecast products. Nevertheless, lightning data is considered to be a valuable commodity that has significant value to other government and commercial users, so there is potential for cost recovery from additional communities beyond aviation once the network is installed. Therefore, EarthSat recommends that UAEAC install 25 lightning sensors and build its own processing center to ensure the availability and quality of the data, and these initial costs will be recovered from the aviation community. After the network is operational, it is reasonable to assume that part of ongoing costs can be recovered from communities other than aviation. For example, if permitted, UAEAC could charge IDEAM and the Colombian Air Force (FAC) for access to the data and there may be electrical utilities other than Interconexión Eléctrica S.A. (ISA) that wish to purchase the data from UAEAC. As a conservative assumption, EarthSat will assume that 25 percent of the ongoing maintenance costs of the lightning detection network can be recovered from user communities other than aviation.

7.3.1.3 Doppler Weather Radar

In Technical Option 3, EarthSat recommends that UAEAC install a Doppler Weather Radar in the Bogotá area. As was done with the U.S. Doppler Weather Radars, EarthSat proposes that this system be installed and operated as a joint effort between UAEAC, IDEAM and FAC. The WMO techniques for determining which proportion of this radar should be allocated to UAEAC requires usage information from a system that is operational. Given the lack of this information, EarthSat will simply assume that the ongoing costs of the radar will be divided evenly between UAEAC, IDEAM and FAC. Therefore, only one third of the ongoing costs can be recovered from the aviation community through user fees. Once the radar is actually operational, UAEAC can review the products from the radar actually used in aviation applications and revise the proportion of costs that can be recovered accordingly.

7.3.1.4 Mesoscale Modeling Center

In Technical Option 3, EarthSat recommends that UAEAC lead a multi-agency collaboration to create a Mesoscale Modeling Center that would develop and operate high-resolution mesoscale weather prediction models for Colombia and northwestern South America. As with the radar, the partners could well include FAC and IDEAM, but EarthSat also recommends the Universidad Nacional de Colombia be included. It is difficult to apply the suggested WMO techniques for determining which proportion of this center should be allocated to UAEAC because it is not yet operational. Given the lack of this information, EarthSat will simply assume that the ongoing costs of the center will be divided evenly between UAEAC, IDEAM, and FAC. While the Universidad Nacional de Colombia will participate, their participation will most likely be through the provision of qualified staff who will monitor and improve the system performance and give scientific and technical guidance. Therefore, only one third of the ongoing costs can be recovered from the aviation community through user fees. Once the center is actually

operational, UAEAC can review the amount of support from the center used in aviation applications and revise the proportion of costs that can be recovered accordingly
.

7.3.2 Calculation of Fair Value of Aeronautical Products and Services (Step 4)

The fair value calculation goal was to follow the ICAO guidance that " *Governments should not require the agency to recover a specific proportion of their total budget from the users. "Over recovery" whereby an agency is required to recover more than the cost of a particular activity in order to fund other unrelated Government commitments is particularly inappropriate."* Following the process described in previous sections of this report and shown in the spreadsheets listed in Appendix B, the fair value of the Aeronautical products and services implementing Technical Option 2 with the Canadian Management Model (5.2B) is $18,919,000 (U.S.) for the 10 years of the project.

7.3.3 Distribute Costs Across Different Classes of User in the Aviation Services (Step 5)

This step is performed to ensure that the various classes of users in the aviation community pay a share of the costs that is in proportion to their usage of aeronautical meteorology products and services. In Document 9082, ICAO states that the

> *"... costs of all meteorological services provided to civil aviation should, where appropriate, be allocated between air traffic services provided for airports and air traffic services provided en route. In States where more than one international airport is involved, consideration could be given to allocating the costs attributable to airport utilization between the airports concerned."*

ICAO provides additional direction on allocating costs across multiple classes of users in Document 9161.

1. *The allocation of aeronautical costs among users should be carried out in a manner equitable to all users.*
2. *The allocation should be made in such a way that costs are recovered from the appropriate users.*
3. *The allocation should be based on the phase of the flight operation, in which the facilities or services are used.*

Following the ICAO guidelines, EarthSat reviewed the air traffic volume information in Section 13 of Working Paper 1 and found that Colombia has about 900,000 flight operations (take-offs and landings) each year but only about 52,000 overflights. This is a ratio of about 20 to 1. EarthSat therefore recommends that only 5% of the ongoing costs of the modernization be collected from the enroute users and 95% from those users performing flight operations in Colombia. By using this ratio, UAEAC's cost recovery program meets the guidelines of ICAO Document 1961. This allocation is also appropriate because much of the modernization effort is directed at improving the quality and number of METARS, and those are directly used by the airlines performing flight operations in Colombia. Because the number of flight operations at each airport is available, UAEAC has the data needed to create unique cost recovery fees for each airport as mentioned in ICAO Document 9082. However, EarthSat recommends that for the initial implementation of the cost recovery fees that UAEAC simply allocate the costs between enroute and flight operations. The goal of the modernization is to create a uniform set of ICAO Annex 3 compliant services across all of the controlled airports in Colombia. Therefore users should pay the same fee across all airports.

7.3.4 Calculation of User Fees

The 2003 WMO Survey on Cost Recovery identified three main techniques used around the world to recover costs from aviation users of aeronautical meteorological products and services.

1. Through a designated entity for all Air Navigation Services in a country (40%)
2. Directly from the airlines (18%)
3. Directly from the Government (4%)

UAEAC is the designated entity for all the Air Navigation Services and Aviation Meteorology Services in Colombia. However, the fees that are currently collected for overflights and airport operations are sent directly to the Government, and UAEAC must obtain its funding for both types of services through the government's budgeting process. This practice makes it difficult for UAEAC to obtain a dependable revenue stream to support the modernization of the aeronautical meteorology system. EarthSat is therefore recommending the implementation of a mechanism to retain the additional overflight and operations fees collected by UAEAC that are designated specifically to support the ongoing costs of the modernization.

This mechanism should be created in the Colombian Government's budget system and receive the fees designated for the ongoing costs of the modernized system, and most importantly, ensure that they are used only for that purpose. The U.S. has a similar system that supports the entire aviation infrastructure. This mechanism will guarantee the availability of the long-term support for the modernized system over the 10 years required to implement it. This long-term funding is critical to maintaining a system that produces reliable, accurate products, and flight and operations fees designated for the modernization support costs.

However, this mechanism does have the drawback that UAEAC cannot spend more on the ongoing costs of the modernized system than are available. Because of this limitation, we will average the annual costs over the 10-year period to calculate the specific overflight and operations fees designated for the modernization support costs. By using this value in the calculations, we can establish a fixed fee for the 10-year period that will ensure that the fund can build a surplus to allow for unexpected expenditures. This surplus can also periodically be drawn down to pay for purchasing upgrades to the modernized system over time. Specifically, because the marginal benefit/cost utility of each element of Technical Option 3 was positive, the EarthSat team recommends that UAEAC use surplus funds to purchase items such as a radar, lightning detection network, etc. as funds become available.

We used the following process to calculate the user fees for each financing option.

1. Calculate the percentage of the costs to be borne by each element using the ratio of overflights to flight operations. (e.g 52,000 overflights divided by 900,000 flight operations)

2. Divide the average annual cost for the 10 years of the program by the lowest annual number of operations for each element (e.g. $4,000,000 divided by 900,000 flight operations) to find the cost per operation.
3. Multiply the percentage of costs to be borne by each element by the cost per operation for that element to spread the costs proportionally between the enroute and operational users.

To provide the maximum amount of guidance to UAEAC, the EarthSat team calculated the user fees needed to support the modernization assuming three different financing options.

1. **Upfront Loan**
    - The user fees do not start until the third year of the program
    - UAEAC takes a single loan to cover the entire costs of the modernization program at the start of the program.
2. **Borrow as Needed**
    - The user fees do not start until the third year of the program
    - UAEAC takes a series of smaller loans in the early years of the program to cover the expenses until the user fees start.
3. **Self Funding**
    - The user fees start in the first year of the program and supply all the funding for the program.

The results of our calculations for each option are shown in Table 7.3 for the three different options.

Financing Option	Operations Fee	Overflight Fee
Upfront Loan	$3.57	$3.77
Borrow as Needed	$3.34	$3.53
Self Funding	$2.79	$2.95

Table 7.3: User Fees Needed to Support the Modernization

To determine which of the three financing options is the best, the EarthSat team conducted a cash flow analysis for each one and the results are described below. In this analysis, we assume that:

1. The number of total flight operations in Colombia will grow by 3.3% per year following with the guidance provided in Working Paper 1, and
2. The modernization costs are based on using Technical Option 2 with the Management Option 5.2B (Canadian Model).

The complete analysis for each option is available in the spreadsheets listed in Appendix B.

Upfront Loan
In the first analysis, the EarthSat team assumed an up front loan of $8,600,000 with a ten year term at 9% annual interest to support the program initially because the user fees and the mechanism to retain them are not implemented until year three of the modernization. This

scenario creates a large surplus beginning in year six that would have to be drawn down substantially in order to follow the ICAO guidance of not charging the users fees that exceed the value of services. The results of this analysis are shown in Figure 7.4.

Borrow as Needed

The second analysis conducted was assuming that loans could be secured on an as needed basis, with cost recovery collections beginning in year three. The results of this analysis are shown in Figure 7.2. The required loan schedule is shown in Table 7.4. User Fees would not have to be increased during the period. Some system upgrades could begin by year six. This may be the most practical option because it may be too optimistic to assume that user fees and the mechanism to retain them could be put in place at the start of the program. A more cost effective version of this scenario is for UAEAC to replace the loans with funds from their annual budget, eliminating the need for interest payments and reducing the user fees below those of the self funding option ($2.44 for operations, $2.58 for overflights).

Loan Summary	Amount	Interest Rate	Years
Year 1	$2,600,000	9%	10
Year 2	$3,500,000	9%	9

Table 7.4 Required Loan Schedule

Self Funding

The third analysis, shown in Figure 7.2, makes the assumption that the user fees and the mechanism to retain them could be put in place quickly. If the mechanism to retain the fees could be implemented at the onset of the program, the fees could be kept lower with no increase, no loans would be needed, and the implementation program would generate surpluses necessary to fund the UAEAC cost share of the upgrades.

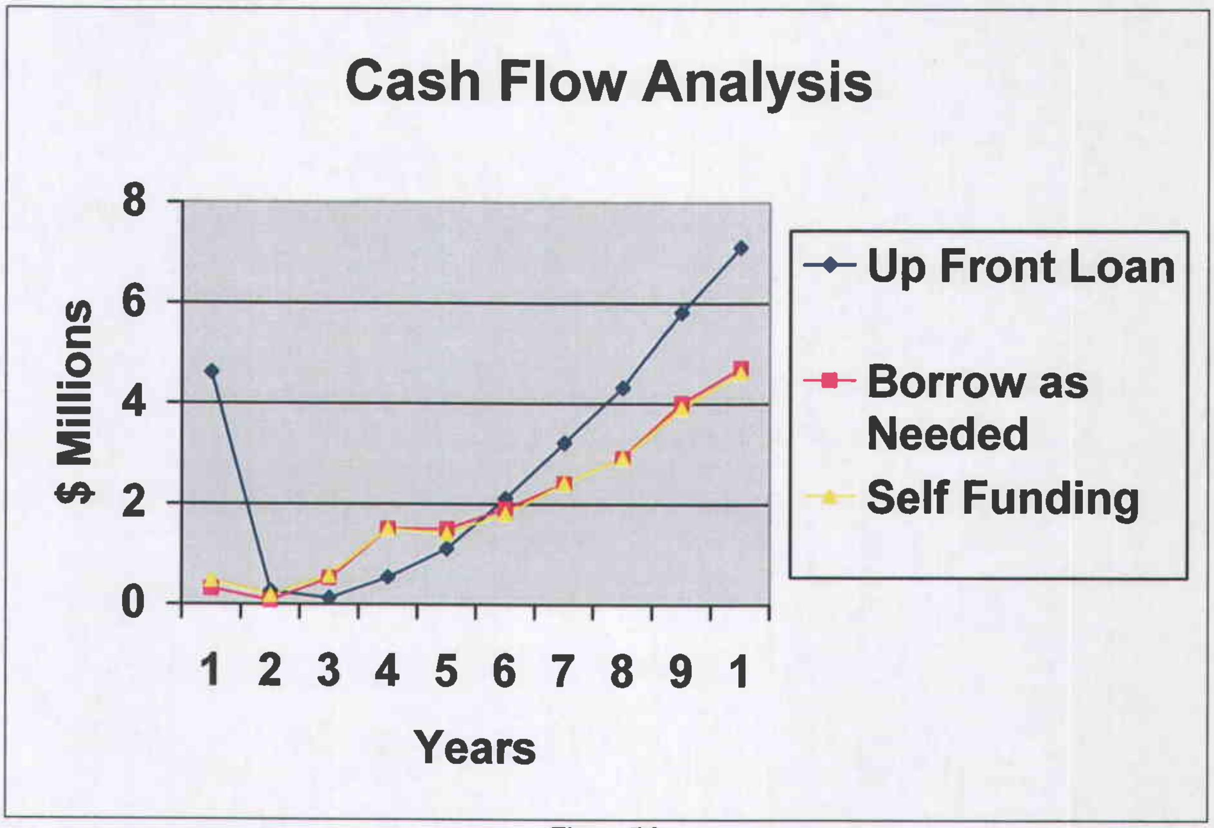


Figure 7.2

7.4 Soliciting User Feedback

The WMO and ICAO stress the need to review any plans for cost recovery with the affected user groups, and EarthSat recommends that UAEAC include this step in the cost recovery development process. The goal of obtaining feedback from the users is to make sure they understand the products and services they will be receiving for the user fees and the process used to calculate those fees. By providing this information, UAEAC can demonstrate the improvements that the users will see in the products and services they receive as well as the fact that the fees are not funding non-aviation activities. UAEAC should also create a mechanism to collect suggestions from the users on ways to improve the program and a mechanism to track the review and implementation of those suggestions. This feedback process should be performed before the fees are implemented and continue on at least an annual basis.

8 SUMMARY

In Working Papers 2 and 3 EarthSat proposed a phased development plan for the modernization of the Colombian Aeronautical Meteorology System. This plan will enable UAEAC to meet the requirements of ICAO Annex 3 for all controlled airports and address the deficiencies noted in the report from the Sixth Meeting of the CAR/SAM Aeronautical Meteorology Subgroup held in Brasilia, Brazil (ICAO, 2003). In this Working Paper, EarthSat examined the financial and environmental aspects of our proposed plan and obtained information on potential equipment vendors. EarthSat decided that it would be beneficial to perform the financial analyses requested in Working Paper 4 using a stepwise approach. First, benefit/cost analyses for three technical implementation options that represent different levels of financial investment for UAEAC were investigated. The highest benefit/cost technical option was selected for further evaluation. For the technical option, with the highest benefit/cost ratios, five organizational options were investigated. The one with the highest benefit/cost ratio was selected for cost/recovery analyses. The option with the best cash flow was then selected as the recommended implementation. The purpose of these additional analyses is to provide the additional unique insights that are critical for UAEAC to successfully implant the modernization program.

8.1 Benefit/Cost Analysis of Technical Options

Based on discussions with UAEAC, we used the three different technical options from Working Paper 2 and performed a benefit cost analysis on each of those options. The equipment and systems included in each option are listed in Table 8.1. Note that all three options include the establishment of a Colombian Aeronautical Meteorological Center in Bogotá that is operational 24x7.

Equipment and Systems Inventory		
Option 1	**Option 2**	**Option 3**
Basic Control Tower Met Systems RVR and Ceilometers for ILS Runways Comprehensive AWOS Replacement Systems Airport Met Networking Upgrades Forecast Data Integration Workstation Software Templates for AIREP and SIGMET Pre-flight (Pilot) Briefing System & Software Communications Upgrades (MET data distribution) Weather Systems for Training and Calibration Airport Web Cameras	Basic Control Tower Met Systems RVR and Ceilometers for ILS Runways Comprehensive AWOS Replacement Systems Airport Met Networking Upgrades Forecast Data Integration Workstation Software Templates for AIREP and SIGMET Pre-flight (Pilot) Briefing System & Software Communications Upgrades (MET data distribution) Weather Systems for Training and Calibration Airport Web Cameras	Basic Control Tower Met Systems RVR and Ceilometers for ILS Runways Comprehensive AWOS Replacement Systems Airport Met Networking Upgrades Forecast Data Integration Workstation Software Templates for AIREP and SIGMET Pre-flight (Pilot) Briefing System & Software Communications Upgrades (MET data distribution) Weather Systems for Training and Calibration Airport Web Cameras Lightning Detection Network Doppler Weather Radar Windshear Detection & Monitoring Systems Mesoscale Modeling Center Radiosonde program

Table 8.1 Inventory of Equipment and Systems for each of the Modernization Options

EarthSat has provided the spreadsheets used to calculate the expenditures and benefits for all Technical Options for a ten-year period extending. These spreadsheets also contain the present value calculations assuming a .03 and a .05 discount rate. Table 8.2 contains the results of the benefit cost analysis for each option and the name of the spreadsheet containing the analysis

Option	Description	Value	Name of File Showing Calculation
1	Upgrade 16 airports	180	Tech_Option_1_Benefit_Cost_Analysis_Revised
2	Upgrade 48 airports	347	Tech_Option_2_Benefit_Cost_Analysis_Revised
3	Implement all items	247	Tech_Option_3_Benefit_Cost_Analysis_Revised

Table 8.2 Technical Benefit / Cost Ratio Calculations

Technical Option 2 is expected to yield a saving of 36 observer position salaries by the end of 2014. Based on history, the equipment upgrades are expected to prevent 16 small aircraft crashes and prevent two major airline crashes during the ten-year period. These preventions would yield a savings of approximately 240 lives during the period. Productivity would increase 5% per year. Benefits due to efficiencies in aircraft operations are expected to yield 1,915,992 aircraft operations that will save on average 30 minutes. This results in much larger benefits to airlines and travelers than Technical Option 1 because Option 1 does not affect as many flight operations and passengers. Technical Option 2 has a better benefit cost ratio than Option 3 due to the higher upgrade costs included in Option 3.

8.2 Benefit/Cost Analysis of Organizational Options

After our review of the technical options showed that Technical Option 2 had the highest benefit/cost ratio, the EarthSat team proceeded to analyze Technical Option 2 implemented with five organizational options as detailed in sections 5.1 to 5.4 of the Task 3 report. These options were:

- 5.1 -- Do nothing
- 5. 3 -- Outsource the program for five years (Concession Model)
- 5.4 -- Implement the program solely with UAEAC personnel
- 5.2A -- Implement following the U.S. Model
- 5.2B -- Implement following the Canadian Model

EarthSat has provided the spreadsheet used to calculate the expenditures and benefits for the Organizational Options for a 10-year period. These spreadsheets are presented in separate files. These spreadsheets also contain the present value calculations assuming a .03 and a .05 discount rate. We selected these two discount rates to roughly model the current rate of inflation. The summary table for the benefit/cost ratios for the five organizational options is shown in Table 8.3.

Option	Value	Name of File Showing Calculation
5.1 Do nothing	0	No calculation was performed
5.3 Concession Model	209	Org_Option_5.3_Benefit_Cost_Analysis_Revised
5.4 UAEAC takes over	204	Org_Option_5.4_Benefit_Cost_Analysis_Revised
5.2A Follow U.S. Model	316	Org_Option_5.2A_Benefit_Cost_Analysis_Revised
5.2B Follow Canadian Model	328	Org_Option_5.2B_Benefit_Cost_Analysis_Revised

Table 8.3 Organizational Benefit / Cost Ratio

Under Organizational Option 5.2B all surface airport observations would stay with UAEAC and IDEAM would provide all additional services, including TAFs, SIGMETs, and AIRREPs. UAEAC would negotiate a contract with IDEAM for the services using either grants or cost recovery described in the following sections. This option provides the highest benefit/cost ratio because it efficiently uses the resources of both organizations.

8.2 Cost Recovery Analysis

As the designated Meteorological Authority for Colombia, UAEAC is responsible for the provision of aeronautical meteorological services that meet the international standards and recommended practices found in ICAO Annex 3. EarthSat recommends that UAEAC implement a cost recovery program to provide the revenue to sustain and evolve the modernization. EarthSat developed a cost recovery plan for the ongoing costs of Technical Option 2 implemented following the Canadian Model. It is important to note that as the designated Meteorological Authority in Colombia, UAEAC is the only agency that can recover costs for the aeronautical meteorological modernization directly from aviation interests.

We calculated the fees using the process shown in Figure 8.1.

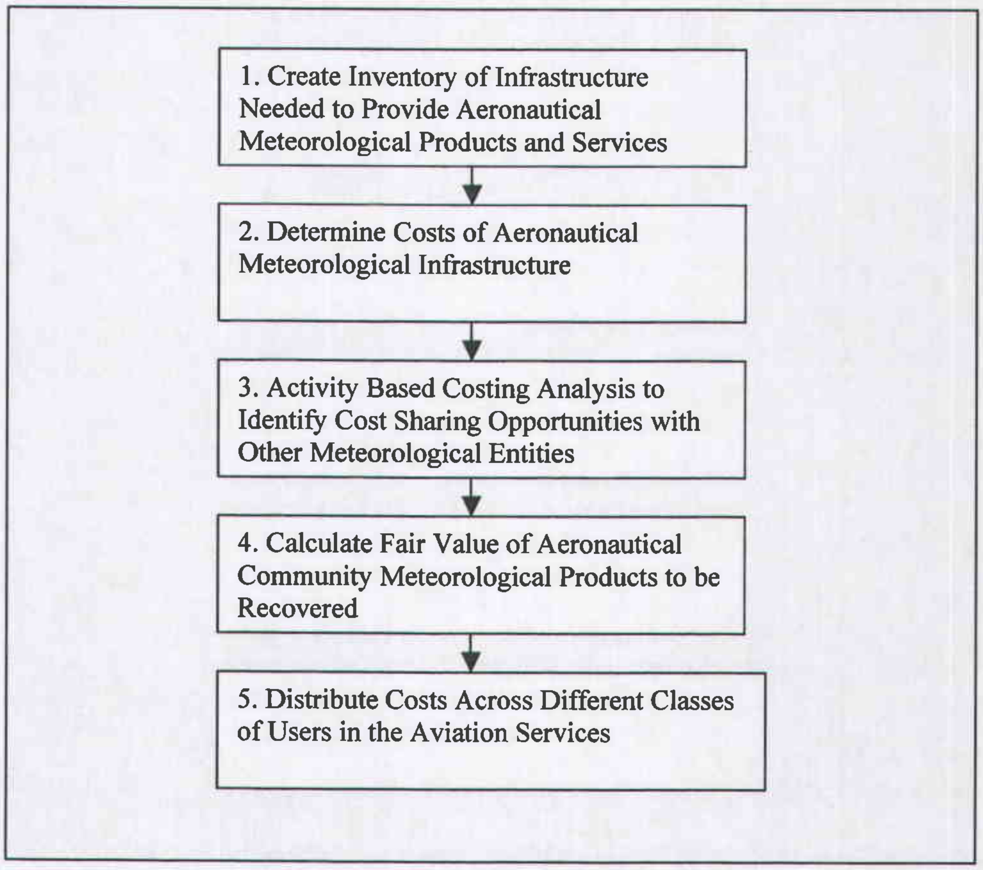


Figure 8.1 EarthSat Cost Recovery Development Process

To provide the maximum amount of guidance to UAEAC, the EarthSat team calculated the user fees needed to support the modernization assuming three different financing options.

1. **Upfront Loan**
    - The user fees do not start until the third year of the program
    - UAEAC takes a single loan to cover the entire costs of the modernization program at the start of the program.
2. **Borrow as Needed**
    - The user fees do not start until the third year of the program
    - UAEAC takes a series of smaller loans in the early years of the program to cover the expenses until the user fees start.
3. **Self Funding**
    - The user fees start in the first year of the program and supply all the funding for the program

The results of our calculations for each option are shown in Table 7.3 for the three different options.

Financing Option	Operations Fee	Overflight Fee
Upfront Loan	$3.57	$3.77
Borrow as Needed	$3.34	$3.53
Self Funding	$2.79	$2.95

Table 8.4 User Fees Needed to Support the Modernization

To determine which of the three financing options is the best, the EarthSat team conducted a cash flow analysis for each one and the results are described below. In this analysis, we assume that

1. The number of total flight operations in Colombia will grow by 3.3% per year following with guidance in Working Paper 1, and
2. The modernization costs are based on using Technical Option 2 with the Management Option 5.2B (Canadian Model).

The results of the cast flow analysis are shown in Figure 8.2.

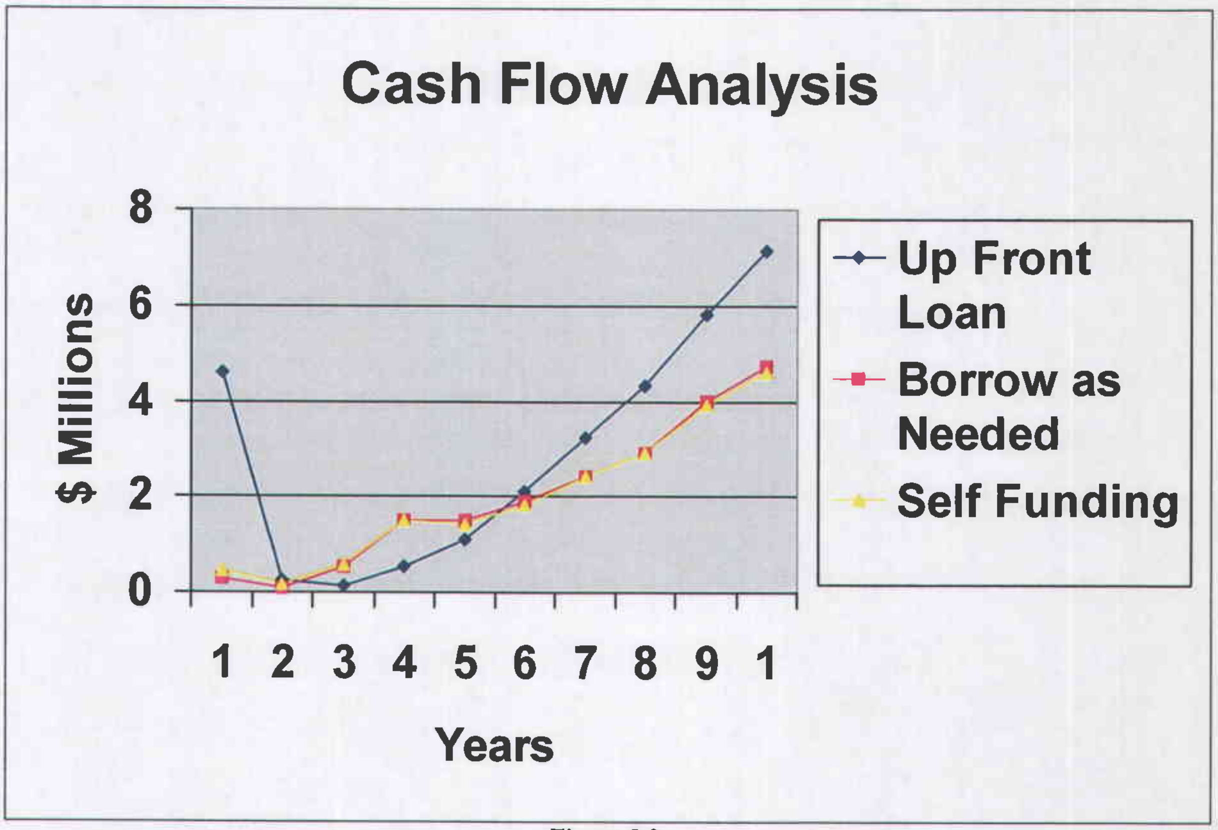


Figure 8.2

8.3 Environmental Impact

EarthSat assessed the impact of the modernization using environmental assessment procedures that are similar to the steps the U.S. takes to assess the environmental implications of proposals for legislation, and other major government actions that might significantly affect the quality of the human environment. Upgrading the Colombian Aeronautical Meteorological System is a major government program lasting ten years or more and involving two major government organizations that conduct operations throughout Colombia. The environmental assessment process provides a systematic way of evaluating the overall effects of the program as a whole, and the relative impacts of each of the major parts of the program, since some actions or procedures will have more impact than others. Our assessment of each option is described below.

8.3.1 Technical Option 1

Option 1 proposes upgrading the AWOS-3, upgrading the radionsonde network, placing Web cams at 16 controlled airports and adding RVR and ceilometers systems to selected ILS and airports with higher numbers of daily flights. In general these weather observation systems pose no major environmental threats unless there are some environmental circumstances in particular environments that warrant further evaluation as referred to in the examples above. No lightning detectors or larger observational systems like weather radars that might have a potential for some adverse environmental effects, are proposed for deployment in this option.

Modifying the software and weather workstations and display systems, upgrading communications, training observers, briefers and forecasters and enhancing their ability to prepare METARs and TAFs should have no impact on the environment.

8.3.2 Technical Option 2

Option 2 proposes upgrading all 48 controlled airports to the AWOS-3 sensors, upgrading the radionsonde network, placing Web cams and providing TAF capability on the remaining airports. As in Option 1, no larger observational systems like weather radars, which might have a potential for some adverse environmental effects, are proposed for deployment in this option. Modifying the software and weather workstations and display systems, upgrading communications, training observers, briefers and forecasters and enhancing their ability to prepare METARs and TAFs should have no impact on the environment.

8.3.3 Technical Option 3

Option 3 proposes all of the upgrades included in Options 1 and 2, as well as some additional large-scale items. In this option we suggest AWOS-3 at all controlled airports, 25 to 32 lightning detectors at sites countrywide, and a single Doppler radar to be installed in Bogotá. We can assume that the AWOS systems, as stated above, with some possible exceptions, will cause no significant environmental disruptions. The radar sites and lightning detectors should be evaluated individually and for the cumulative affects on the environment of all of the systems.

EarthSat also assessed the potential for the use of solar power for meteorological equipment in Colombia. We recommend that, as a general long-term goal, Colombia should upgrade all their controlled airports to have reliable electrical power (including backup generators for essential systems, as required) and high speed (broadband) data communication links. Colombia should not be forced to use solar power at controlled airports because line power isn't available or reliable, or have airports that can't communicate (both voice and digital data) with the rest of the national aviation system. Although it is rare in Colombia, any airports where ice is a problem would require line power for instrument heaters. We recommend that UAEAC examine the need for instrument heaters at two airports, Bogota and Ipiales (both located at high altitudes). Potential solar installations should be first be evaluated for climatological hours of sunlight. Some mountain sites may be problematic. Similarly, airports that experience high winds (such as San Andres with the recent hurricane) may have problems with the solar panels being subject to wind damage. Line power, on the other hand, would have to be evaluated on the basis of its reliability and frequency of outages (both currently and after any planned national power system upgrades).

In summary, we recommend that Aero Civil install solar power systems for instruments at many airports where it is practical but we believe it is essential for reliable operations that a plan be developed for future upgrades to line power (with backup generators).

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Viénot, D. March 22, 2005: By the side of the indigenous populations in Colombia. Caritas Europa.

APPENDIX A: EQUIPMENT, SYSTEMS AND SOFTWARE VENDORS

All Weather, Inc.
West Coast (Headquarters)
1165 National Drive
Sacramento, CA 95834 USA
Toll Free: 800-824-5873
Tel: 916-928-1000
Fax: 916-928-1165
Office Hours: 8:00 AM to 4:30 PM PST

East Coast
Federal Systems and Integrated Displays
144 Lakefront Drive
Hunt Valley, MD 21030 USA
Toll Free: 800-935-2767
Tel: 410-229-7539
Fax: 410-229-7602
Office Hours: 8:00 AM to 4:30 PM EST

ARINC, Incorporated
2551 Riva Road
Annapolis, MD 21401 USA
Tel: (800) 663-6882
Fax: (410) 573-3300

Belfort Instruments
Belfort Instrument Company
727 South Wolfe Street
Baltimore, MD 21231 USA
Sales Toll Free: (800) 937-2353
Service Toll Free: (888) 937-2353
Tel: (410) 342-2626

CLR Photonics
Corporate Headquarters
Coherent Technologies, Inc.
135 South Taylor Ave.
Louisville, Co 80027 USA
Tel: (303) 604-2000
Fax: (303) 604-2500

Coastal Environmental Systems, Inc.
820 First Avenue South
Seattle, WA 98134 USA
Tel: 206-682-6048
Toll-Free: 800-488-8291
Fax: 206-682-5658

Global Science and Technology
Corporate Headquarters
7855 Walker Drive, Suite 200
Greenbelt, MD 20770 USA
Tel: (301) 474-9696
Fax: (301) 474-5970

International Met System (InterMet)
4460 40th St. SE
Grand Rapids, MI 49512 USA
Tel: (616) 285-7810
Fax: (616) 957-1280

Microsoft Corporation
One Microsoft Way
Redmond, WA 98052-6399 USA
Tel: 1-800-MICROSOFT
(1-800-642-7676)
Fax: 1-425-93-MSFAX
(1-425-936-7329)

Paroscientific, Inc.
4500 148th Ave. N.E.
Redmond, WA, 98052 USA
Tel: (425) 883-8700
Fax: (425) 867-5407

Potomac Aviation Technology Corp.
10 Newberry Street
Boston, MA 02116 USA
Tel: (617) 267-6828
Toll-Free: (800) 207 8999

SeaSpace Corporation
12120 Kear Place
Poway, CA 92064 USA
Tel: 1-858-746-1100
Fax: 1-858-746-1199
Customer Service: 1-858-746-1160

Sigmet, Inc.
2 Park Drive, Unit 1
Westford, MA 01886-3528 USA
Tel: 978-692-9234
Fax: 972-692-9575

Sippican, Inc. (Lockheed Martin Sippican)
7 Barnabas Road
Marion, MA 02738 USA
Tel: (508) 748-1160
Fax: (508) 748-3626

Sutron Corporation
21300 Ridgetop Circle
Sterling, VA 20166 USA
Tel: (703)406-2800
Fax: (703)406-2801

Teledyne Controls Headquarters
12333 West Olympic Blvd.
Los Angeles, California 90064 USA
Tel: 310-820-4616
Fax: 310-442-4324

Vaisala
Houston Office, Houston, Texas, USA.
1120 NASA Road, Suite 220-E
Houston, TX 77058 USA
Tel: 281-335-9955
Fax: 281-335-9956

APPENDIX B: LIST OF SPREADSHEETS TRANSMITTED SEPARATELY TO UAEAC

SPREADSHEETS CREATED FOR WORKING PAPER 4

Technical Option Benefit Cost Analysis

Content	Filename
Option 1	Tech_Option_1_Benefit_Cost_Analysis_Revised
Option 2	Tech_Option_2_Benefit_Cost_Analysis_Revised
Option 3	Tech_Option_3_Benefit_Cost_Analysis_Revised

Organization Option Benefit Cost Analysis

Content	Filename
Option 5.2A (US Model)	Org_Option_5.2A_Benefit_Cost_Analysis_Revised
Option 5.2B (Canadian Model)	Org_Option_5.2B_Benefit_Cost_Analysis_Revised
Option 5.3(Concession)	Org_Option_5.3_Benefit_Cost_Analysis_Revised
Option 5.4 (UAEACI)	Org_Option_5.4_Benefit_Cost_Analysis_Revised

Cash Flow Analysis

Content	Filename
Upfront Loan	CASH_FLOWS_COLOMBIA_Loan_upfront_Revised.xls
Loans as Needed	CASH_FLOWS_COLOMBIA_Loan_as_Needed_Revised.xls
Self Funding	CASH_FLOWS_COLOMBIA_Self_Funding_Revised.xls

Modernization Costs T
Basic Control Tower MET Sys
RVR and Ceilometers for ILS
Comprehensive AWOS Repla
GOES Receiving Systems (20
WAFS Workstation (acquired
Airport MET Networking Upgr
Forecaster Data Integration W
Software Templates for AIREI
Pre-flight (Pilot) Briefing Syst
Local Pre-flight Weather Brie
Communication Upgrades (M
Weather Systems for Training
Airport Web Cameras
Radiosonde and Upper Air Sc
Radiosonde Operations
Replacement Costs
Equipment Total
New Staffing Requirements
Personnel Training
Misc. Expenses (Import taxes
Other Costs Total
Maintenance Cost
TOTAL COSTS

Modernization Benefits ($100
Automation of Observing Op
Improved Safety (Aircraft an
Improved Productivity of Sta
Efficiency of Aircraft operati
Time Saving for Travelers
TOTAL BENEFITS

Benefits Inputs:
number of positions eliminated - obse
salary observer (US$)
number of small aircraft saved per ye
average value of general aviation airc
number of large commercial aircraft s
average value of a commercial aircra
number of lives saved per year
average value of a human life (US$)
number of staff
percent improved productivity
annual salary of staff (US$)
number of aircraft operations
number of aircraft operations affecte
average time saved per aircraft opera
value of flight hour (US$)
average passenger load per flight
value of passenger time (US$)
flight hours saved

Labor Estimates:
Aerocivil:
observer/briefer
estimated salary
Total Aerocivil Salaries
IDEAM
Director met office
Director Salary
supervisors
Supervisor Salary
Meteorologist
Meteorologist Salary
observer/briefer
estimated salary
Total IDEAM Salaries
Total Program Salaries
Total IDEAM Staff
Total Staff
Average salary Aerocivil Staff
Average salary IDEAM Staff
Average Salary all staff
Met Center Labor Costs

Modernization Co
Basic Control Tower MET
RVR and Ceilometers for
Comprehensive AWOS R
GOES Receiving System
WAFS Workstation (acqu
Airport MET Networking
Forecaster Data Integrati
Software Templates for A
Pre-flight (Pilot) Briefing
Local Pre-flight Weather
Communication Upgrade
Weather Systems for Tra
Airport Web Cameras
Radiosonde and Upper A
Radiosonde Operations
Replacement Costs
Equipment Total
Personnel Training
Misc. Expenses (Import
Other Costs Total
Maintenance Cost
TOTAL COSTS

Modernization Benefits
Automation of Observin
Improved Safety (Aircra
Improved Productivity o
Efficiency of Aircraft op
Time Saving for Travele
TOTAL BENEFITS

Benefits Inputs:
number of positions eliminated
salary observer (US$)
number of small aircraft saved
average value of general avia
number of large commercial ai
average value of a commercia
number of lives saved per yea
average value of a human life
number of staff
percent improved productivity
annual salary of staff
number of aircraft operations
number of aircraft operations
average time saved per aircra
value of flight hour
average passenger load per f
value of passenger time
flight hours saved

Labor Estimates:
Aerocivil:
observer/briefer
estimated salary
Total Aerocivil Salaries
IDEAM
Director met office
Director Salary
supervisors
Supervisor Salary
Meteorologist
Meteorologist Salary
observer/briefer
estimated salary
Total IDEAM Salaries
Total Program Salaries
Total IDEAM Staff
Total Staff
Average salary Aerocivil Sta
Average salary IDEAM Staff
Average Salary all staff
Met Center Labor Costs

Modernization Cost Technical Option 3
Basic Control Tower MET Systems
RVR and Ceilometers for ILS Runways
Comprehensive AWOS Replacement Program
GOES Receiving Systems (2004 purchase)
WAFS Workstation (acquired in 2004)
Airport MET Networking Upgrades
Forecaster Data Integration Workstation
Software Templates for AIREP and SIGMET
Pre-flight (Pilot) Briefing System & Software
Local Pre-flight Weather Briefing, User Workstations
Communication Upgrades (MET data distribution)
Weather Systems for Training & Calibration
Airport Web Cameras
Radiosonde and Upper Air Soundings
Radiosonde Operations
Replacement Costs
Equipment Total
Personnel Training
Misc. Expenses (import taxes, Permits, etc.)
Other Costs Total
Maintenance Cost
Sub Total Basic Items
Recommended Options
Lightning Detection Network
Maintenance & Support Lightning Network
Consultant Services (site selection)
Doppler Weather Radar
Maintenance & Support for Doppler Radar
Consultant Services (radar systems and installation)
Windshear Detection & Monitoring Systems
Maintenance & Support for Windshear Systems
Consultant Services (terrain induced windshear)
Mesoscale Modeling Center
Maintenance & Support Costs for Computer Center
Consultant Services (model setup and support)
Sub Total Recommended Options & Maintenance
New Staffing Requirements
Personnel Training
Misc. Expenses (import taxes, Permits, etc.)
Total Other Costs Recommended Options & Maint.
Total Recommended Options & Maint.
Total All Costs

Modernization Benefits (in 1000$)
Automation of Observing Operations
Improved Safety (Aircraft and Insurance)
Improved Productivity of Staff
Efficiency of Aircraft operations
Time Saving for Travelers
TOTAL BENEFITS

Benefits Inputs:
number of positions eliminated - observer
salary observer (US$)
number of small aircraft saved per year
average value of general aviation aircraft
number of large commercial aircraft saved per year
average value of a commercial aircraft (US$)
number of lives saved per year
average value of a human life (US$)
number of staff
percent improved productivity
annual salary of staff
number of aircraft operations
number of aircraft operations affected by weather at 48 airports
average time saved per aircraft operation (hours)
value of flight hour (US$)
average passenger load per flight
value of passenger time(US$)
flight hours saved

Labor Estimates:
Aerocivil:
observer/briefer
estimated salary
Total Aerocivil Salaries
IDEAM
Director met office
Director Salary
supervisors
Supervisor Salary
Meteorologist
Meteorologist Salary
observer/briefer
estimated salary
Total IDEAM Salaries
Total Program Salaries
Total IDEAM Staff
Total Staff
Average salary Aerocivil Staff
Average salary IDEAM Staff
Average Salary all staff
Met Center Labor Costs

Modernization Costs Assuming U.S. Model (5.2A)	Calendar Year Expenditures (US $ x 1000)				
	Year 0	Year 1	Year 2	Year 3	Year 4
AeroCivil Costs					
Basic Control Tower MET Systems		$ 30.00	$ 30.00	$ 30.00	$ 30
RVR and Ceilometers for ILS Runways		$ 250.00	$ 300.00		$ 120
Comprehensive AWOS Replacement Program		$ 400.00	$ 780.00	$ 420.00	$ 380
GOES Receiving Systems (2004 purchase)					
WAFS Workstation (acquired in 2004)					
Airport MET Networking Upgrades			$ 25.00	$ 25.00	$ 25
Pre-flight (Pilot) Briefing System & Software				$ 250.00	
Local Pre-flight Weather Briefing, User Workstations					$ 30
Communication Upgrades (MET data distribution)		$ 45.00	$ 45.00	$ 45.00	$ 45
Weather Systems for Training & Calibration		$ 20.00	$ 20.00	$ 100.00	$ 20
Airport Web Cameras		$ 20.00	$ 20.00	$ 20.00	$ 20
Replacement Costs					
AeroCivil Equipment Costs	$ -	$ 765.00	$ 1,220.00	$ 890.00	$ 670
New FSS Staffing					
Personnel Training		$ 38.25	$ 61.00	$ 44.50	$ 33
Misc. Expenses (Import taxes, Permits, etc.)		$ 76.50	$ 122.00	$ 89.00	$ 67
Other AeroCivil Costs	$ -	$ 114.75	$ 183.00	$ 133.50	$ 100
AeroCivil Maintainence Costs	$ -	$ 14.62	$ 81.70	$ 172.00	$ 258
TOTAL AEROCIVIL COSTS	$ -	$ 894.37	$ 1,484.70	$ 1,195.50	$ 1,028

IDEAM COSTS:	Year 0	Year 1	Year 2	Year 3	Year 4
Forecaster Data Integration Workstation			$ 300.00		
Software Templates for AIREP and SIGMET			$ 50.00	$ 150.00	
Radiosonde and Upper Air Soundings		$ 150.00	$ 40.00		
Radiosonde Operations			$ 200.00	$ 400.00	$ 400
Communication Upgrades (MET data distribution)		$ 5.00	$ 5.00	$ 5.00	$ 5
Replacement Costs					
IDEAM Equipment Costs Total		$ 155.00	$ 595.00	$ 555.00	$ 405
Personnel Training		$ 7.75	$ 29.75	$ 27.75	$ 20
Misc. Expenses (Import taxes, Permits, etc.)		$ 15.50	$ 59.50	$ 55.50	$ 40
Other IDEAM Costs Total		$ 23.25	$ 89.25	$ 83.25	$ 60
IDEAM Maintenance Costs		$ 2.38	$ 13.30	$ 28.00	$ 42
Staffing Cost Offset		$ (48.00)	$ (96.00)	$ (144.00)	$ (216
Productivity Cost Offset		$ (57.42)	$ (110.03)	$ (157.84)	$ (198
Total IDEAM Costs		$ 75.21	$ 491.52	$ 364.41	$ 95
Total Upgrade Costs		$ 969.58	$ 1,976.22	$ 1,559.91	$ 1,124

Modernization Benefits:	Year 0	Year 1	Year 2	Year 3	Year 4
Automation of Observing Operations	$ -	$ -	$ -	$ -	$
Improved Safety (Aircraft and Insurance)	$ -	$ 103,800.00	$ 103,800.00	$ 103,800.00	$ 103,800
Improved Productivity of Staff	$ -	$ 11.40	$ 22.80	$ 34.20	$ 45
Efficiency of Aircraft operations	$ -	$ 230,529.16	$ 238,136.63	$ 245,995.13	$ 254,112
Time Saving for Travelers	$ -	$ 213,030.25	$ 220,060.25	$ 227,322.24	$ 234,823
TOTAL BENEFITS	$ -	$ 547,370.81	$ 562,019.67	$ 577,151.57	$ 592,782

AeroCivil Benefits Inputs:	Year 0	Year 1	Year 2	Year 3	Year 4
number of positions eliminated - observer	0	0	0	0	
salary observer (US$)	$ 12,000	$ 12,000	$ 12,000	$ 12,000	$ 12,0
number of small aircraft saved per year	0	1	1	1	
average value of general aviation aircraft	$ 2,000,000	$ 2,000,000	$ 2,000,000	$ 2,000,000	$ 2,000,0
number of large commercial aircraft saved per year	0	0.2	0.2	0.2	
average value of a commercial aircraft	$ 149,000,000	$ 149,000,000	$ 149,000,000	$ 149,000,000	$ 149,000,0
number of lives saved per year	0	24	24	24	
average value of a human life	$ 3,000,000	$ 3,000,000	$ 3,000,000	$ 3,000,000	$ 3,000,0
number of staff	19	19	19	19	
percent improved productivity	0	0.05	0.1	0.15	
annual salary of staff	$ 12,000	$ 12,000	$ 12,000	$ 12,000	$ 12,0
number of aircraft operations	982,023	1,014,430	1,047,906	1,082,487	1,118,
number of aircraft operations affected by weather at 48 airports	147,303	152,164	157,186	162,373	167,
average time saved per aircraft operation (hours)	0	0.5	0.5	0.5	
value of flight hour	$ 3,030	$ 3,030	$ 3,030	$ 3,030	$ 3,0
average passenger load per flight	80	80	80	80	
value of passenger time	$ 35.00	$ 35.00	$ 35.00	$ 35.00	$ 35
flight hours saved	0	76,082	78,593	81,187	83,

IDEAM Benefits:	Year 0	Year 1	Year 2	Year 3	Year 4
number of positions eliminated - observer		4	8	12	
salary observer (US$)	$ 12,000	$ 12,000	$ 12,000	$ 12,000	$ 12,0
$ Saved		$ 48,000	$ 96,000	$ 144,000	$ 216,0
number of staff	99	95	91	87	
percent improved productivity	0	0.05	0.1	0.15	
annual salary of staff	$ 12,085	$ 12,088	$ 12,091	$ 12,095	$ 12,

Labor Estimates:					
Aerocivil:	Year 0	Year 1	Year 2	Year 3	Year 4
observer/briefer	19	19	19	19	
estimated salary	$ 12,000	$ 12,000	$ 12,000	$ 12,000	$ 12,0
Total Aerocivil Salaries	$228,000	$228,000	$228,000	$228,000	$228,0
IDEAM					
Director met office	1	1	1	1	
Director Salary	$ 30,000	$ 30,000	$ 30,000	$ 30,000	$ 30,0
supervisors	5	5	5	5	
Supervisor Salary	$ 12,000	$ 12,000	$ 12,000	$ 12,000	$ 12,0
Meteorologist	16	16	16	16	
Meteorologist Salary	$11,500	$11,500	$11,500	$11,500	$11,5
observer/briefer	77	73	69	65	
estimated salary	$ 12,000	$ 12,000	$ 12,000	$ 12,000	$ 12,0
Total IDEAM Salaries	$1,198,000	$1,150,000	$1,102,000	$1,054,000	$982,0
Total Program Salaries	$1,426,000	$1,378,000	$1,330,000	$1,282,000	$1,210,0
Total IDEAM Staff	99	96	93	90	
Total Staff	118	115	112	109	
Average salary Aerocivil Staff	$12,000	$12,000	$12,000	$12,000	$12,0
Average salary IDEAM Staff	$ 12,101	$ 12,105	$ 12,110	$ 12,115	$ 12,
Average Salary all staff	$ 12,085	$ 12,088	$ 12,091	$ 12,095	$ 12,
Met Center Labor Costs	$ 430,000	$ 430,000	$ 430,000	$ 430,000	$ 430,0

Modernization Costs Assuming Canadian Model (5.2B)	Calendar Year Expenditures (US $ x 1000)				
	Year 0	Year 1	Year 2	Year 3	Year 4
AeroCivil Costs					
Basic Control Tower MET Systems		$ 30.00	$ 30.00	$ 30.00	$ 30
RVR and Ceilometers for ILS Runways		$ 250.00	$ 300.00		$ 120
Comprehensive AWOS Replacement Program		$ 400.00	$ 780.00	$ 420.00	$ 380
GOES Receiving Systems (2004 purchase)					
WAFS Workstation (acquired in 2004)					
Airport MET Networking Upgrades			$ 25.00	$ 25.00	$ 25
Communication Upgrades (MET data distribution)		$ 45.00	$ 45.00	$ 45.00	$ 45
Weather Systems for Training & Calibration		$ 20.00	$ 20.00	$ 100.00	$ 20
Airport Web Cameras		$ 20.00	$ 20.00	$ 20.00	$ 20
Replacement Costs					
AeroCivil Equipment Costs	$ -	$ 765.00	$ 1,220.00	$ 640.00	$ 640
Personnel Training		$ 38.25	$ 61.00	$ 32.00	$ 32
Misc. Expenses (Import taxes, Permits, etc.)		$ 76.50	$ 122.00	$ 64.00	$ 64
Other AeroCivil Costs	$ -	$ 114.75	$ 183.00	$ 96.00	$ 96
AeroCivil Maintainence Costs	$ -	14.62	61.70	172.00	25
TOTAL AEROCIVIL COSTS	$ -	$ 894.37	$ 1,484.70	$ 908.00	$ 994

IDEAM COSTS:	Year 0	Year 1	Year 2	Year 3	Year 4
Forecaster Data Integration Workstation			$ 300.00		
Software Templates for AIREP and SIGMET			$ 50.00	$ 150.00	
Pre-flight (Pilot) Briefing System & Software				$ 250.00	
Local Pre-flight Weather Briefing, User Workstations					$ 30
Radiosonde and Upper Air Soundings		$ 150.00	$ 40.00		
Radiosonde Operations			$ 200.00	$ 400.00	$ 400
Communication Upgrades (MET data distribution)		$ 5.00	$ 5.00	$ 5.00	$ 5
Replacement Costs					
IDEAM Equipment Costs Total	$ -	$ 155.00	$ 595.00	$ 805.00	$ 435
Personnel Training		$ 7.75	$ 29.75	$ 40.25	$ 21
Misc. Expenses (Import taxes, Permits, etc.)		$ 15.50	$ 59.50	$ 80.50	$ 43
Other IDEAM Costs Total		$ 23.25	$ 89.25	$ 120.75	$ 65
IDEAM Maintenance Costs		$ 2.38	$ 13.30	$ 28.00	$ 42
Staffing Reduction Cost Offset	$ -	$ (36.00)	$ (72.00)	$ (108.00)	$ (168
Productivity Cost Offset		$ (58.10)	$ (112.60)	$ (163.50)	$ (206
Total IDEAM Costs (excluding salaries)		$ 86.53	$ 512.95	$ 682.25	$ 168
Total Upgrade Costs (AEROCIVIL plus IDEAM)		$ 980.90	$ 1,997.65	$ 1,590.25	$ 1,162

Modernization Benefits:	Year 0	Year 1	Year 2	Year 3	Year 4
Automation of Observing Operations	$ -	$ -	$ -	$ -	$
Improved Safety (Aircraft and Insurance)	$ -	$ 103,800.00	$ 103,800.00	$ 103,800.00	$ 103,800
Improved Productivity of Staff	$ -	$ 11.40	$ 22.80	$ 34.20	$ 45
Efficiency of Aircraft operations	$ -	$ 230,529.16	$ 238,136.63	$ 245,995.13	$ 254,112
Time Saving for Travelers	$ -	$ 213,030.25	$ 220,060.25	$ 227,322.24	$ 234,823
TOTAL BENEFITS	$ -	$ 547,370.81	$ 562,019.67	$ 577,151.57	$ 592,782

Benefits Inputs AeroCivil:

	Year 0	Year 1	Year 2	Year 3	Year 4
number of positions eliminated - observer	0	0	0	0	
salary observer (US$)	$ 12,000	$ 12,000	$ 12,000	$ 12,000	$ 12,(
number of small aircraft saved per year	0	1	1	1	
average value of general aviation aircraft	$ 2,000,000	$ 2,000,000	$ 2,000,000	$ 2,000,000	$ 2,000,(
number of large commercial aircraft saved per year	0	0.2	0.2	0.2	
average value of a commercial aircraft (US$)	$ 149,000,000	$ 149,000,000	$ 149,000,000	$ 149,000,000	$ 149,000,(
number of lives saved per year	0	24	24	24	
average value of a human life	$ 3,000,000	$ 3,000,000	$ 3,000,000	$ 3,000,000	$ 3,000,(
number of staff	19	19	19	19	
percent improved productivity	0	0.05	0.1	0.15	
annual salary of staff	$ 12,000	$ 12,000	$ 12,000	$ 12,000	$ 12,(
number of aircraft operations	982,023.00	1,014,429.76	1,047,905.94	1,082,486.84	1,118,20
number of aircraft operations affected by weather at 46 airports	147,303.45	152,164.46	157,185.89	162,373.03	167,73
average time saved per aircraft operation (hours)	0	0.5	0.5	0.5	
value of flight hour (US$)	$ 3,030	$ 3,030	$ 3,030	$ 3,030	$ 3,(
average passenger load per flight	80	80	80	80	
value of passenger time per hour	$ 35	$ 35	$ 35	$ 35	$
flight hours saved	0	76,082.23	78,592.95	81,186.51	83,86

Benefits IDEAM	Year 0	Year 1	Year 2	Year 3	Year 4
number of positions automated	0	3	6	9	
salary observer (US$)	$ 12,000	$ 12,000	$ 12,000	$ 12,000	$ 12,(
$ saved	$ -	$ 36,000	$ 72,000	$ 108,000	$ 168,(
number of staff	99	96	93	90	
percent improved productivity	0	0.05	0.1	0.15	
annual salary of staff	$ 12,101	$ 12,104	$ 12,108	$ 12,111	$ 12,'

Labor Estimates					
Aerocivil:	Year 0	Year 1	Year 2	Year 3	Year 4
observer/briefer	19	19	19	19	
estimated salary	$ 12,000	$ 12,000	$ 12,000	$ 12,000	$ 12,(
Total Aerocivil Salaries	$228,000	$228,000	$228,000	$228,000	$228,(
IDEAM					
Director met office	1	1	1	1	
Director Salary	$ 30,000	$ 30,000	$ 30,000	$ 30,000	$ 30,(
supervisors	5	5	5	5	
Supervisor Salary	$ 12,000	$ 12,000	$ 12,000	$ 12,000	$ 12,(
Meteorologist	16	16	16	16	
Meteorologist Salary	$11,500	$11,500	$11,500	$11,500	$11,(
observer/briefer	77	74	71	68	
Supervisor Salary	$ 12,000	$ 12,000	$ 12,000	$ 12,000	$ 12,(
Total IDEAM Salaries	$1,198,000	$1,162,000	$1,126,000	$1,090,000	$1,030,(
Total Program Salaries	$1,426,000	$1,390,000	$1,354,000	$1,318,000	$1,258,(
Total IDEAM Staff	99	96	93	90	
Total Staff	118	115	112	109	
Average salary Aerocivil Staff	$12,000	$12,000	$12,000	$12,000	$12,(
Average salary IDEAM Staff	$ 12,101	$ 12,104	$ 12,108	$ 12,111	$ 12,
Average Salary all staff	$ 12,085	$ 12,087	$ 12,089	$ 12,092	$ 12,(
Met Center Labor Costs	$ 430,000	$ 430,000	$ 430,000	$ 430,000	$ 430,(

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Replacement Costs
Equipment Total
Additonal Salary Costs
Personnel Training
Misc. Expenses (Import taxes,
Other Costs Total
Maintenance Cost
TOTAL COSTS

Modernization Benefits ($1000)
Automation of Observing Opera
Improved Safety (Aircraft and In
Improved Productivity of Staff
Efficiency of Aircraft operations
Time Saving for Travelers
TOTAL BENEFITS

Benefits Inputs:
number of positions eliminated - observ
salary observer (US$)
number of small aircraft saved per year
average value of general aviation aircra
number of large commercial aircraft sav
average value of a commercial aircraft
number of lives saved per year
average value of a human life
number of staff
percent improved productivity
annual salary of staff
number of aircraft operations
number of aircraft operations affected b
average time saved per aircraft operatio
value of flight hour
average passenger load per flight
value of passenger time
flight hours saved

Labor Estimates:
Aerocivil:
observer/briefer
estimated salary
Total Aerocivil Salaries
IDEAM
Director met office
Director Salary
supervisors
Supervisor Salary
Meteorologist
Meteorologist Salary
observer/briefer
estimated salary
Total IDEAM Salaries
Total Program Salaries
Total IDEAM Staff
Total Staff
Average salary Aerocivil Staff
Average salary IDEAM Staff
Average Salary all staff
Met Center Labor Costs

Casl
Cost

	Year 1	Year 2	Year 3	Year
Beginning Cash Flow	$ -	$ 4,580,110	$ 250,675	$ 112
Incoming Cash Flows				
Landing Fees	$ -	$ -	$ 3,663,088	$ 3,784
Overflight Fees	$ -	$ -	$ 207,942	$ 214
Interest Income		$ 229,005	$ 12,534	$ 5
Loans	$ 8,250,000			
Total Cash Inflows	$ 8,250,000	$ 229,005	$ 3,883,563	$ 4,004
Outgoing Cash Flows				
AeroCivil Salaries	$ 228,000	$ 228,000	$ 228,000	$ 228
Debt Servicing	$ 1,254,090	$ 1,254,090	$ 1,254,090	$ 1,254
Equipment	$ 765,000	$ 1,220,000	$ 640,000	$ 640
Maintainence	$ 14,620	$ 81,700	$ 172,000	$ 258
Training	$ 38,250	$ 61,000	$ 32,000	$ 32
Misc Expenses	$ 77,000	$ 122,000	$ 64,000	$ 64
Payment for IDEAM Salaries	$ 1,162,000	$ 1,126,000	$ 1,090,000	$ 1,030
Other Payments to IDEAM	$ 130,930	$ 465,650	$ 541,150	$ 76
Total Cash Outflows	$ 3,669,890	$ 4,558,440	$ 4,021,240	$ 3,582
Ending Cash Flow	$ 4,580,110	$ 250,675	$ 112,998	$ 534

Cash Flow Inputs:	Year 1	Year 2	Year 3	Year
Total Flight Operations	1,014,430	1,047,906	1,082,487	1,11
Takeoffs/landings	962,430	994,346	1,027,320	1,06
overflights	52,000	53,560	55,167	5
Landing Fee	$0.00	$0.00	$ 3.57	$
Enroute Fee	$0.00	$0.00	$ 3.77	$

Labor Estimates:				
Aerocivil:				
observer/briefer	19	19	19	
estimated salary	$12,000	$12,000	$12,000	$1
Total Aerocivil Salaries	$228,000	$228,000	$228,000	$22
IDEAM				
Director met office	1	1	1	
Director Salary	$30,000	$30,000	$30,000	$3
supervisors	5	5	5	
estimated salary	$12,000	$12,000	$12,000	$1
Meteorologist	16	16	16	
Meteorologist Salary	$11,500	$11,500	$11,500	$1
observer/briefer	74	71	68	
estimated salary	$12,000	$12,000	$12,000	$1
Total IDEAM Salaries	$1,162,000	$1,126,000	$1,090,000	$1,03
Total Program Salaries	$1,390,000	$1,354,000	$1,318,000	$1,25
Total IDEAM Staff	96	93	90	
Total Staff	115	112	109	

Other Payments to IDEAM	Year 1	Year 2	Year 3	Year
Costs excluding Salaries	$ 130,930	$ 599,650	$ 809,150	$ 34
cost sharing offset - Radioson		$ 134,000	$ 268,000	$ 26
Other Payments to IDEAM	$ 130,930	$ 465,650	$ 541,150	$ 7

Cash Flows - Canadi
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	Year 1	Year 2	Year 3	Year 4	Year 5
Beginning Cash Flow	$ -	$ 301,872	$ 67,191	$ 509,959	$ 1,525,221
Incoming Cash Flows					
Landing Fees	$ -	$ -	$ 3,425,404	$ 3,538,442	$ 3,655,210
Overflight Fees	$ -	$ -	$ 195,645	$ 202,101	$ 208,771
Loans	$2,600,000	$3,500,000			
Total Cash Inflows	$ 2,600,000	$ 3,500,000	$ 3,621,048	$ 3,740,543	$ 3,863,981
Outgoing Cash Flows					
AeroCivil Salaries	$ 228,000	$ 228,000	$ 228,000	$ 228,000	$ 228,000
Debt Servicing	$ 395,228	$ 964,031	$ 964,031	$ 964,031	$ 964,031
Equipment	$ 765,000	$ 1,220,000	$ 640,000	$ 640,000	$ 1,151,800
Maintainence	$ 14,620	$ 81,700	$ 172,000	$ 258,000	$ 301,000
Training	$ 38,250	$ 61,000	$ 32,000	$ 32,000	$ 57,590
Misc Expenses	$ 76,500	$ 122,000	$ 64,000	$ 64,000	$ 115,180
Payment for IDEAM Salaries	$ 694,000	$ 679,000	$ 664,000	$ 639,000	$ 614,000
Other Payments to IDEAM	$ 86,530	$ 378,950	$ 414,250	$ (99,750)	$ 503,970
Total Cash Outflows	$ 2,298,128	$ 3,734,681	$ 3,178,281	$ 2,725,281	$ 3,935,571
Ending Cash Flow	$ 301,872	$ 67,191	$ 509,959	$ 1,525,221	$ 1,453,632

Cash Flow Inputs:	2005	2006	2007	2008	2009
Total Flight Operations	1,014,430	1,047,906	1,082,487	1,118,209	1,155,110
Takeoffs/landings	962,430	994,190	1,026,998	1,060,889	1,095,899
overflights	52,000	53,716	55,489	57,320	59,211
Landing Fee	$0.00	$0.00	$ 3.34	$ 3.34	$ 3.34
Enroute Fee	$0.00	$0.00	$ 3.53	$ 3.53	$ 3.53

Labor Estimates:					
Aerocivil:					
observer/briefer	19	19	19	19	19
estimated salary	$12,000	$12,000	$12,000	$12,000	$12,000
Total Aerocivil Salaries	$228,000	$228,000	$228,000	$228,000	$228,000
IDEAM					
Director met office	1	1	1	1	1
Director Salary	$30,000	$30,000	$30,000	$30,000	$30,000
supervisors	5	5	5	5	5
estimated salary	$12,000	$12,000	$12,000	$12,000	$12,000
Meteorologist	16	16	16	16	16
Meteorologist Salary	$11,500	$11,500	$11,500	$11,500	$11,500
observer/briefer	74	71	68	63	58
estimated salary	$12,000	$12,000	$12,000	$12,000	$12,000
Total IDEAM Salaries	$1,162,000	$1,126,000	$1,090,000	$1,030,000	$970,000
Total Program Salaries	$1,390,000	$1,354,000	$1,318,000	$1,258,000	$1,198,000
Total IDEAM Staff	96	93	90	85	80
Total Staff	115	112	109	104	99

Loan summary	amount	interest rate	years
year 1	$ 2,500,000	9%	10
year 2	$ 3,500,000	9%	9
year 3	$ 500,000	9%	8
year 4	$ 500,000	9%	7
year 5	$ 300,000	9%	6

Other Payments to IDEAM	2005	2006	2007	2008	2009
Costs excluding Salaries	$ 86,530	$ 512,950	$ 682,250	$ 168,250	$ 771,970
cost sharing offset - Radioson		$ 134,000	$ 268,000	$ 268,000	$ 268,000
Other Payments to IDEAM	$ 86,530	$ 378,950	$ 414,250	$ (99,750)	$ 503,970

Cash Flo
Self Funding - Can

	Year 1	Year 2	Year 3	Year 4	Year 5
Beginning Cash Flow	$ -	$ 463,639	$ 174,068	$ 558,523	$ 1,530,7
Incoming Cash Flows					
Landing Fees	$ 2,681,389	$ 2,769,875	$ 2,861,281	$ 2,955,703	$ 3,053,2
Overflight Fees	$ 153,150	$ 158,204	$ 163,425	$ 168,818	$ 174,3
Loans/Grants					
Total cash Inflows	$ 2,834,539	$ 2,928,079	$ 3,024,705	$ 3,124,521	$ 3,227,6
Outgoing Cash Flows					
AeroCivil Salaries	$ 228,000	$ 228,000	$ 228,000	$ 228,000	$ 228,0
Equipment	$ 765,000	$ 1,220,000	$ 640,000	$ 640,000	$ 1,151,8
Maintainence	$ 14,620	$ 81,700	$ 172,000	$ 258,000	$ 301,0
Training	$ 38,250	$ 61,000	$ 32,000	$ 32,000	$ 57,5
Misc Expenses	$ 76,500	$ 122,000	$ 64,000	$ 64,000	$ 115,1
Payment for IDEAM Salaries	$ 1,162,000	$ 1,126,000	$ 1,090,000	$ 1,030,000	$ 970,0
Other Payments to IDEAM	$ 86,530	$ 378,950	$ 414,250	$ (99,750)	$ 503,9
Total Cash Outflows	$ 2,370,900	$ 3,217,650	$ 2,640,250	$ 2,152,250	$ 3,327,5
Ending Cash Flow	$ 463,639	$ 174,068	$ 558,523	$ 1,530,794	$ 1,430,8

Cash Flow Inputs:					
	2005	2006	2007	2008	2
Total Flight Operations	1,014,430	1,047,906	1,082,487	1,118,209	1,155,
Takeoffs/landings	962,430	994,190	1,026,998	1,060,889	1,095,
overflights	52,000	53,716	55,489	57,320	59,
Landing Fee	$ 2.79	$ 2.79	$ 2.79	$ 2.79	$ 2
Enroute Fee	$ 2.95	$ 2.95	$ 2.95	$ 2.95	$ 2

Labor Estimates:					
Aerocivil:	2005	2006	2007	2008	2
observer/briefer	19	19	19	19	
estimated salary	$12,000	$12,000	$12,000	$12,000	$12,(
Total Aerocivil Salaries	$228,000	$228,000	$228,000	$228,000	$228,(
IDEAM					
Director met office	1	1	1	1	
Director Salary	$30,000	$30,000	$30,000	$30,000	$30,(
supervisors	5	5	5	5	
Supervisor Salary	$12,000	$12,000	$12,000	$12,000	$12,(
Meteorologist	16	16	16	16	
Meteorologist Salary	$11,500	$11,500	$11,500	$11,500	$11,
observer/briefer	74	71	68	63	
estimated salary	$12,000	$12,000	$12,000	$12,000	$12,(
Total IDEAM Salaries	$1,162,000	$1,126,000	$1,090,000	$1,030,000	$970,
Total Program Salaries	$1,390,000	$1,354,000	$1,318,000	$1,258,000	$1,198,
Total IDEAM Staff	96	93	90	85	
Total Staff	115	112	109	104	

Average salary Aerocivil Staff	$12,000	$12,000	$12,000	$12,000	$12,
Average salary IDEAM Staff	$ 12,104	$ 12,108	$ 12,111	$ 12,118	$ 12,
Average Salary all staff	$ 12,087	$ 12,089	$ 12,092	$ 12,096	$ 12,

Met Center Labor Costs	$ 430,000	$ 430,000	$ 430,000	$ 430,000	$ 430,

Other Payments to IDEAM	2005	2006	2007	2008	
Costs excluding Salaries	$ 86,530	$ 512,950	$ 682,250	$ 168,250	$ 771,
cost sharing offset - Radioson		$ 134,000	$ 268,000	$ 268,000	$ 268,
Other Payments to IDEAM	$ 86,530	$ 378,950	$ 414,250	$ (99,750)	$ 503,

Working Paper Number 5

DISCUSSION OF THE SOURCES OF FINANCING FOR THE INVESTMENT REQUIRED TO MODERNIZE THE AERONAUTICAL METEOROLOGY SYSTEM IN COLOMBIA

Prepared for

Unidad Administrativa Especial de Aeronáutica Civil
Aeropuerto El Dorado
Bogotá, Colombia

by

Earth Satellite Corporation
Avia Structure
February 2006

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1 TERMS OF REFERENCE

1.1 Task 5: Develop Finance Options

The Consultant will evaluate options for financing the Aeronautical Meteorology System Development Plan. Sources of public and private funds will be identified, an action agenda will be developed outlining the steps necessary to apply and/or secure financing under each source, and terms and conditions of potential loans will be identified.

The sources of financing will include public sector financing and financing from commercial capital markets, equity financing from investors, suppliers' credits, bilateral tied credits such as the U.S. Export-Import Bank, and other combinations of options. The Consultant will incorporate in the analysis a discussion of financial risks and suggest mitigating steps.

1.2 Deliverable: Working Paper

A discussion of the sources of financing for the investment required to modernize the aeronautical meteorology system in Colombia and an action agenda outlining future steps needed for UAEAC to pursue financing of investments.

2 FUNDING OPTIONS

2.1 Introduction

Financial options provide multi-year budgets specifying costs of upgrades, new equipment and aggregate costs, by year, for the options over the relevant time frame of the transition period. One of the first steps is to look at infrastructure and determine to what extent existing financial resources (based both on fees collected from airlines and budgetary funds) are available to fund system expansion. Financing options considered for Task 5 fall into three general categories:

- ***Self-funding*** - Potential self-funding strategies such as the revision of fee structure as a method to fund all or part of system, acquisition and implementation costs, or obtaining necessary budget from central government.
- ***Debt Funding*** - These options include financing from private international banks; multinational lending institutions such as the World Bank and the Inter-American Development Bank, plus bilateral credits from the United States Export-Import Bank; supplier credits; or combinations of all or some of these institutions. If projected revenues are sufficient, it may be possible for the debt financing to be tied to user fees collected from air navigation services and structured to service the loan and provide debt repayment (as well as income generation).
- ***Equity Funding*** - Possibility of equity funding through private or public sector investments. Such options might include a Build-Own-Transfer (BOT) or Build-Own-Operate (BOO) option with financing from some combination of equity funds and bonds.

Financing options were assessed per the Task 5 description set forth in the Terms of Reference. In making this assessment, consideration was given to the project size, investment requirements, the costs, and the implementation schedule. In addition, it is assumed that the recipient of the financing will in all likelihood involve a sovereign risk or state-owned and operated entity. Therefore, this analysis assumes that it is the intention of the UAEAC to manage the meteorological system, which generally reduces the possibility of public-private partnerships and the Government's ability to consider financing options that would include the likes of IFC, OPIC, private sector financing operations of IADB, or other institutions supporting private sector related financing. Recent developments in Colombia, however, such as the potential concessioning of El Dorado International Airport, necessitate further analysis of equity funding as a viable model.

Since self-funding represents the most efficient and straightforward method to fund the modernization of aeronautical systems, the EarthSat team focused its efforts on exploring with bilateral, multilateral, regional, and commercial institutions that would support financing involving sovereign risk or state owned and operated entities. These financing options could involve direct loans, loan guarantee, or risk mitigating arrangements that could induce commercial financial institutions or investors to participate in financing through commercial loans and securities issues.

2.2 Self-Funding

Given the relatively small amount of resources required to upgrade Colombia's aeronautical meteorological services, self-funding warrants serious consideration. The EarthSat team maintains that self-funding is the preferred method to fund the upgrading of aeronautical meteorological services in Colombia, since other forms of funding require outside resources that carry the cost of either debt repayment or loss of equity. It is also probable that the safety benefits and increased service-provision derived from the modernization of the meteorological system would adequately justify obtaining the necessary budget from the central government for such an upgrade.

The main risk associated with self-funding relates to the phased nature of modernizing the meteorological service in Colombia. It is necessary that UAEAC receives the entire required funding each year of the modernization. Should funding disappear at any point, the anticipated improvement in terms of safety and increased service could be jeopardized. One risk-mitigation possibility would to request funding for the entire project in the first year. If funding were to dry up in later years, the modernization project would already have been realized.

2.3 Concessioning Strategy

This section discusses concessional and other contractual arrangements, which are prevalent in the aviation sector, especially as it relates to private sector participation in the projects, which UAEAC is contemplating in its effort to upgrade Colombia's aeronautical meteorological system.

For aviation sector operations, numerous countries have employed concessional and other contractual arrangements in which there is private sector participation. These arrangements can be medium and long term in nature and range from the private sector having **outright ownership** and direct project management responsibilities to **joint venture** companies between governments and private sector investors, with the latter having direct project management responsibilities.

Longer term concession arrangements are often utilized for financing and managing major airport operations and incorporate all or part of the design, build, operate, and financial aspects of a project. The medium term concession arrangements tend to be for smaller less capital-intensive projects, but for a particular project's operations, require the unique skills and management expertise offered by private sector entities.

The more appropriate arrangement to consider for meteorological services is likely a medium term structure that is used for a number of landside and airside activities including, among others, ground services, cargo operations, baggage handling, catering, and duty free and other retail services. Such arrangements range from five to ten years, and are contracts between the appropriate government agency and the private sector party providing the service. There are entities, which can provide such service including ARINC (USA) and SITA (Switzerland).

For these operations, the government may enter into a management contract, but retain full ownership of the entity, its assets, and operations. In other cases, the private sector entity, in addition to its full management responsibility of operations, may acquire directly or through a joint venture, all existing assets and purchase new assets, with the agreement that after the expiry of the contractual arrangement, assets and operations revert to UAEAC. This joint venture might include government participation. Also note that the public and/or private ownership structure under concessions and similar contractual arrangements is heavily influenced by a country's foreign investment and other relevant laws, governing such entities and their sector.

Under these arrangements, private sector management and technical support can improve a particular operation's efficiency, productivity, and profitability. As an incentive to achieve this end, performance measures (e.g., costs and revenues) are often times included as part of the overall compensation package in the joint venture agreement and serve as a basis for paying incentive fees when meeting such measures.

In addition, this arrangement can be used as a means of training and developing agency personnel with the end result in this case being UAEAC's ability to internally manage operations after the contract's expiry. This skills set or technology transfer could also be considered a performance measure in the contract between UAEAC and the concessionaire.

Finally, private technical support in the form of a concession, can often times be a pre-condition to receiving favorable financing terms from commercial and official financing sources. With regard to U.S. Government financiers, Overseas Private Investment Corporation (OPIC), the U.S. agency which supports foreign direct investment by U.S. firms, can provide insurance, direct loans, and guarantees for cross border projects in which U.S. corporations participate, including those which enter into long term management contracts. In the case of UAEAC, a 10 year management contract would meet OPIC's basic criteria.

Our findings and conclusions are as follows:

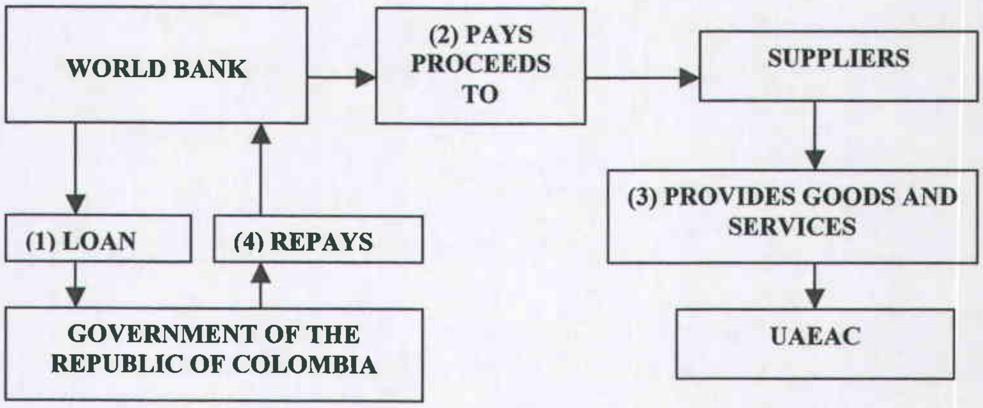
- **Concession:** As stated in 4.4.2 Outsource the Program to a Contractor for Five Years, the initial conclusions by EarthSat leads to some initial question as to the viability of a concession for UAEAC's meteorological operations. In order to determine whether or not there is viability, a more detailed analysis is warranted and this would include among others, a valuation of existing assets and operations, incorporate the likely capital improvement costs, the development of forecasts for revenue streams and operating costs, and the identification of alternative debt and equity financing structures and options, and the selection criteria for and identification of prospective concessionaires, and UAEAC's oversight responsibilities.
- **Management Contract:** Another option to consider would be one in which there is continued ownership by UAEAC of UAEAC, but UAEAC enters into a management contract with an outside party which is experienced with providing meteorological services. This would include companies such as ARINC (USA) or SITA (Switzerland). The decision to enter into such arrangement would be predicated on a conclusion arrived at by UAEAC that such action would improve the efficiency, productivity, and profitability of UAEAC's operations as well as provide a higher level of service and safety to airlines and other users.
- **Commingling:** In that the revenue stream associated with this project is small, another consideration would be to structure a concession or management contracts which might commingle UAEAC's meteorological service with IDEAM's operations or with other UAEAC operations (e.g. telecom), thereby creating greater economies of scale for prospective private sector providers.
- **Legal Regulatory:** In all cases, it will be critical to conduct a review of relevant Colombian legal regulatory aspects governing private sector and foreign entity participation in operations of this nature.

2.4 Key Financial Institutions

The key multilateral/bilateral institutions are as follows:

2.4.1 World Bank Group (WBG)

The WBG provides an array of financing options including **investment loans,** which are direct loans to finance goods, works, and services in support of economic and social development projects in a broad range of sectors. These direct loans typically run for five to ten years. The transaction flow for a direct loan from the World Bank is described below:



As an alternative, the Bank's political risk mitigating products help encourage private capital flows to emerging market countries by providing a degree of protection against critical government-performance risks that private lenders are reluctant to assume. The Project Finance and Guarantees Department offers three types of **WBG guarantees** to commercial lenders:

1. **Partial Credit Guarantees** cover a portion of scheduled repayments of private loans or bonds against all risks. These guarantees are usually provided for privately funded public projects.
2. **Partial Risk Guarantees** cover debt services defaults on loans to private-sector projects caused by government failures to meet contractual obligations.
3. **Policy Based Guarantees** cover portions of debt service on borrowing by eligible member countries from private foreign creditors in support of agreed structural, institutional and social policy reforms.

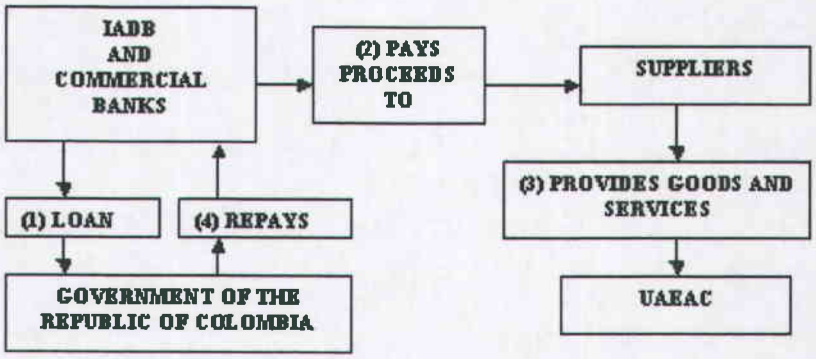
The application process for the WBG commences with the Resident Representatives Office in Bogotá where a recommendation is made as to whether the project should commence the project review cycle as described herein. If the recommendation is affirmative, other relevant departments including any with industry specialization would become team members involved in the cycle, which is described herein.

2.4.2 Inter American Development Bank (IADB)[1]

IADB uses loans, grants, guarantees and investments to fund development programs in Latin America and the Caribbean. Loans, grants and guarantees are used for public and private investment projects, for policy reforms, to help countries cope with financial crises or disasters, and for national and regional technical cooperation. The majority of the Bank's projects and technical cooperation programs are financed through loans, whether at market rates or using concessional resources, and has standard terms and conditions.

[1] Source: http://www.iadb.org/exr/country/eng/colombia/

Often, IADB will co-finance transactions with commercial banks by syndicating a portion of the financing. The transaction flow is described below:



The initial approach to IADB for consideration would be with the Resident Representative's Office in Bogotá where a recommendation is made as to whether the project should commence the project review cycle as described herein. When the IADB has all the necessary information, a transaction typically takes three to six months from initial contact to signing. In some cases, however, this can be shorter. The total project cycle, from initiation to repayment, can range from one year for working capital or trade financing projects up to 15 years for long-term sovereign infrastructure projects.

2.4.3 The Andean Development Corporation (CAF)[2]

The Andean Development Corporation (CAF) is a multilateral financial institution that promotes the sustainable development of its shareholder countries and regional integration. Serving both public and private sectors, the CAF offers a wide range of financial services to a broad client base composed of the governments of shareholder countries (which include Colombia), public and private companies and financial institutions. Its policies incorporate social and environmental variables, and all its operations are governed by criteria of eco-efficiency and sustainability. The CAF has maintained a permanent presence in its shareholder countries, which has strengthened its regional leadership in terms of effective mobilization of resources. The Corporation is currently the leading source of multilateral financing for the countries of the Andean Community, contributing 55% of total funds approved by multilateral agencies from 1997 to 2002. It was recently announced that CAF in July, approved a $150 million loan to the Republic of Colombia to finance road infrastructure and regional development. [3]

The CAF's core businesses are closely related to the two basic pillars of its mission: reinforce and expand its role as promoter of Latin American integration, and strengthen the sustainability approach in all its operations. The Corporation aims its services at the

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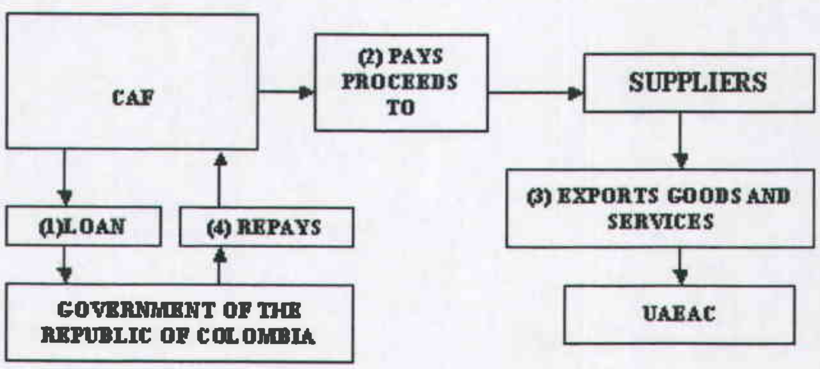
[2] Source: http://www.caf.com
[3] Source: Latin Finance /September 2005 edition

governments of **shareholder countries**, and the public institutions and private companies or joint ventures that operate in them. The range of services is similar to that offered by commercial, development and investment banks, with emphasis on optimizing the Corporation's competitive advantages in the areas of infrastructure, industry and financial systems; favoring the integration of public and private action in the shareholder countries; and strengthening its catalytic, innovative and integrationist role in the region.

CAF Products and Services:

- Loans at short, medium and long terms.
- Project structuring and financing without recourse or limited recourse.
- Co-financing with multilateral institutions and international banks.
- Investment and financial consulting services
- Guarantees and avals
- Equity investments
- Treasury services
- Technical cooperation
- Strategic programs

The transaction flow for a CAF loan is described below:



2.4.4 Export Import Bank of the United States (Ex-Im Bank)

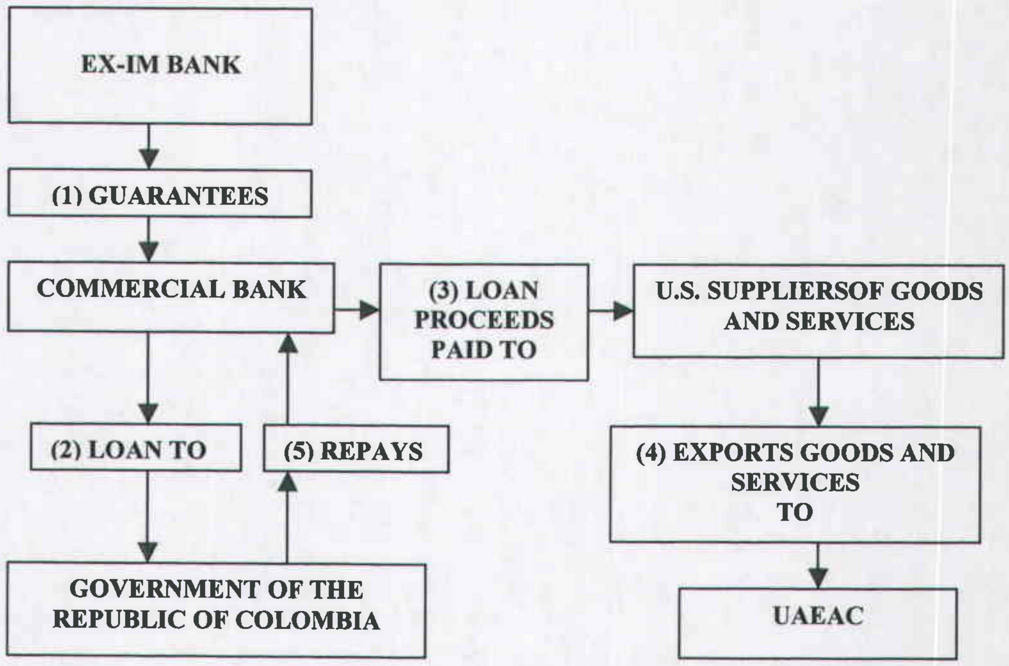
Ex-Im Bank support can be made through guarantees and direct loans from Ex-Im Bank. Under its loan and guarantee programs, Ex-Im Bank will finance or guarantee up to 85%

of the export. The interest rate associated with the borrowing for a loan guaranteed by Ex-Im Bank will reflect the fact that this guarantee carries the full faith and credit of the United States Government. In addition, Ex-Im Bank charges a risk exposure fee, which is a risk premium charged by all export credit agencies and it is based on a political and credit risk analysis that Ex-Im Bank does from time to time. This risk exposure fee can be reduced significantly through risk mitigants such as pledging IATA receipts as collateral.

It should be further noted that if UAEAC intended to purchase goods from multiple countries, there are cases where Ex-Im Bank will co-finance export sales with export credit agencies of other countries including among others, Canada, United Kingdom, Japan, and Italy.

Recently, Ex-Im approved a $24.0 million transaction with the Colombian Ministry of Defense for aircraft (helicopters). There has also been a transaction where the Colombian Ministry of Finance was the borrower for aircraft in 1999 ($47.0 million) and 2000 ($156.0 million).

The transaction flow for an Ex-Im Bank guaranteed transaction is described below:

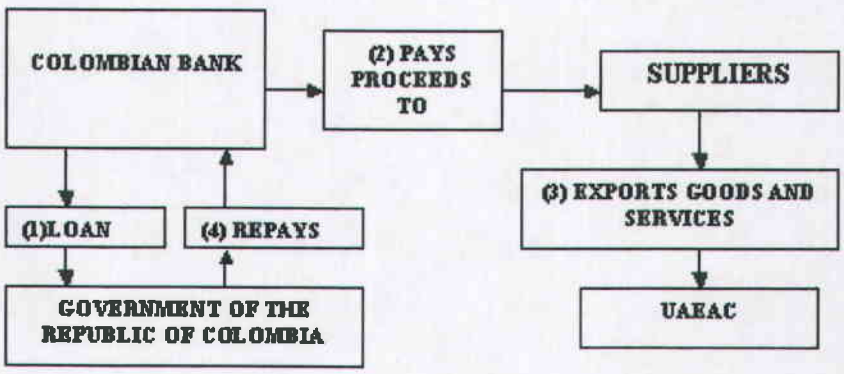


With respect to the application process, Ex-Im Bank provides exporters and borrowers support at various stages of the export process. For example, if an exporter is participating in a tender or is in a negotiation stage in which the exporter must demonstrate the ability to finance exports, in this case to the Government of Colombia, Ex-Im Bank will issue a **Letter of Interest** as an indication of Ex-Im Bank's willingness to consider financing a given export transaction. The exporter could also apply for a **preliminary commitment,** which is a commitment by Ex-Im Bank to provide financing subject to the exporter is awarded an export contract. Finally, the exporter or borrower can apply for a **final commitment,** which is an authorization of financing by Ex-Im Bank. The application for a final commitment occurs when the export contract has been awarded. The **final commitment** will specify the risk exposure fee, which can be financed by Ex-Im Bank or paid up front by the borrower. Note that it is not necessary to have a letter of interest or preliminary commitment before applying for a final commitment.

2.5 Commercial Banks

The top-tier Colombian commercial banks are well-capitalized institutions that have the capacity to fund through deposits or international market sources, the recommended capital expenditures for the recommended meteorological project, as well as a commingling of a number of projects. In addition, these banks have the ability to guarantee export credit agency financing including that which Ex-Im Bank might provide. This, however, could be a cause for higher transaction costs and thus, there would have to be some overriding reason for UAEAC to utilize a commercial banking institution for export credit agency financing.

The transaction flow for a commercial bank loan is described below:



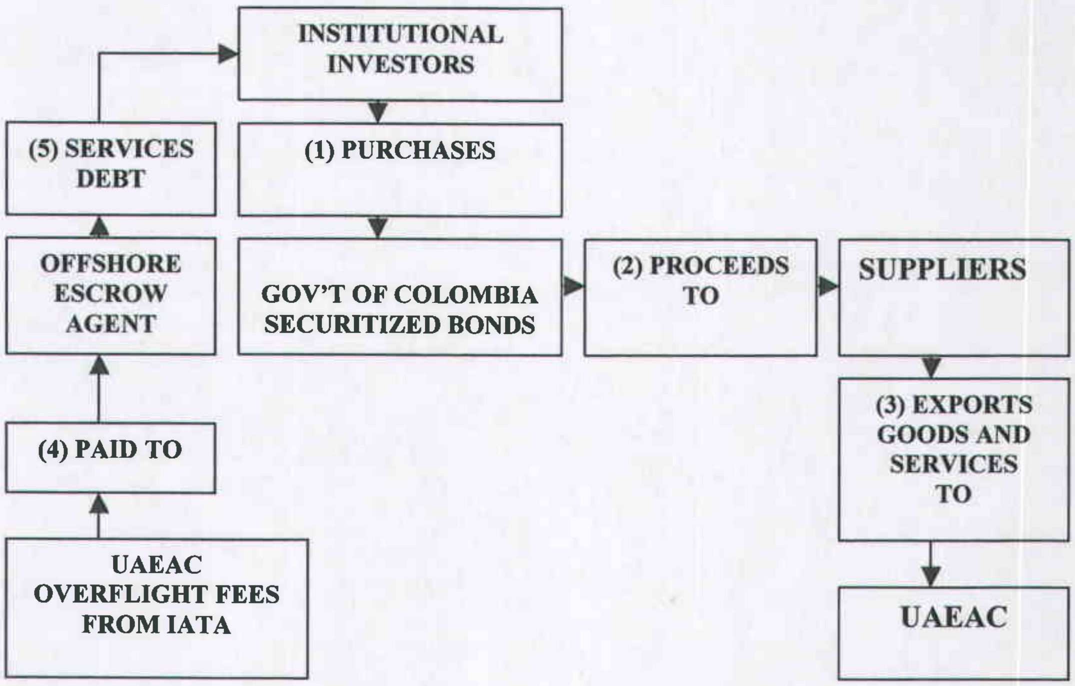
2.6 Bond Issues

The Government of the Republic of Colombia has been an active issuer of securities in the international markets. For example, it was announced that Colombia began selling $500 million dollar-denominated bonds maturing in 2024, reopening its January 2004 issue. Goldman Sachs and Merrill Lynch are managing the sale. This follows an announcement in September 2005 that as a measure to better manage its foreign exchange risk exposure, Colombia will buy back $700 million in euro- and dollar-denominated bonds due 2006 and 2033[4]. Assuming continued access to the international markets, the Government has the capacity to finance infrastructure projects not only through its internal revenue generation, but also from the proceeds of transactions accessing the international financial markets.

[4]Source: *Latin Finance-Daily Brief,* September 16, 2005

Another consideration would be utilize proceeds generated from hard currency over-flight and landing fees to finance future UAEAC capital expenditures by using said fees as the basis for issuing securitized securities in the international markets. The consultant refers to the finding discussed earlier in Section 4.4 entitled *Organization* in which it was discussed that over-flight and landing fees are "frequently redirected to the general Colombian budget." With these proceeds and the institution of proper modalities including acceptable escrow arrangements, the Government of Colombia would be in a position to issue highly rated securities, which versus other financing options discussed herein, could generate meaningful interest rate savings.

The transaction flow for a securitized bon issue would be as follows:



2.7 Soft Credits

EarthSat looked at multilateral organizations and bilateral donors as prospective sources of soft money. With respect to multilaterals, the financial institutions such as the World Bank or Inter American Development Bank normally restrict soft credits / money to lesser developing countries, and with Colombia's favorable economic performance, it does not qualify for such financing.

EarthSat also considered relevant international organizations including the Technical Cooperation Bureau of the International Civil Aviation Organization (ICAO) and World Meteorological Organization (WMO). These organizations are effectively limited to grant assistance under technical cooperative arrangements, which are similar to support provided by USTDA under its Technical Assistance and Feasibility Study programs. EarthSat then conferred with the Federal Aviation Administration, and while it and the

U.S. Department of Transportation provide soft money support to other regions (e.g. Africa), no such program exists for Latin America. Instead the FAA often works with USTDA and ICAO's Technical Cooperation Bureau in only providing technical assistance.

EarthSat then explored the prospect of financing support that might be forthcoming from bilateral aid donors. The conclusion was that for the most part, these bilateral donors have provided foreign aid to Colombia in such areas as governance, poverty reduction, education, and agricultural development and food. For example, in discussions with USAID, EarthSat learned that while in the past, it had provided funding for aviation and other infrastructure related projects, its current focus was on drug interdiction and alternative economic development, principally in rural areas. Restrictions are also due in part to budgetary constraints on the part of donor countries which based on discussions with the recipient country, must prioritize how its employs aid money that is at the donor's disposal. We further note that global standards on technologies and equipment for meteorological systems however, limit the universe of prospective donors having the ability to provide standardized goods and services. Finally, because of Colombia's access to the international capital markets and its development of internal markets, there is the capacity to finance more and more projects commercially.

There have been exceptions to the norm, and an example is Plan Colombia (or any derivative) in which the United States Government, under the administration of the U.S. Department of State provided inter-agency assistance to meet the most pressing challenges confronting Colombia, namely promoting the peace process, combating the narcotics industry, reviving the Colombian economy, and strengthening the democratic pillars of Colombian society. Assuming that criteria can be met, there could be funds available under similar programs that could serve as a financing source for this project.

Notwithstanding, it is suggested that UAEAC explore with the appropriate ministries that they interact with donors to discern if any of Colombia's donors would consider supporting a project of this nature through normal donor programs or specific programs such as that which Plan Colombia provided until it expired in September 2005. If affirmative, the prospective donor in all likelihood would require that the majority of the goods and services emanate from their country. Finally, the approval process would require a package similar to that described in the recommendations for packaging financing requests to multilateral and bilateral financing agencies as described in UAEAC Task 5.

2.8 Conclusions and Recommended Strategic Course of Action

As discussed, there are multiple financing options that UAEAC might consider when financing the recommended capital program, but the size of the capital program is relatively small for many of these options. In the consultant's opinion, a critical factor on deciding how to move forward will be a function of whether UAEAC decides to finance this project on an individual basis or to commingle this project with other CNS/ATM or other civil aviation projects. Another commingling alternative would be to combine this project with project expenditures under consideration by IDEAM, especially if the specifications have commonalities with the recommended capital program for UAEAC.

Once this decision is taken, the consultant recommends the following course of action:

1. Self-funding is a highly desirable option and should be pursued, if funds are available, to implement the entire technical alternative ultimately selected by UAEAC.
2. In order to determine whether a concessioning strategy is viable, a more detailed analysis is warranted, and this would include, among others, a valuation of existing assets and operations; incorporate the likely capital improvement costs; the development of forecasts for revenue streams and operating costs, and the identification of alternative debt and equity financing structures and options; and the selection criteria for and identification of prospective concessionaires, and UAEAC's oversight responsibilities.
3. The UAEAC should consider engaging a Technical/Financial Advisor, which can assist UAEAC with the presentation, details of the tender process, and alternative financing structures that these institutions might consider.
4. The UAEAC and the Ministry of Finance or appropriate Government of Colombia liaison should contact IADB, WBG, and Ex-Im Bank and present these institutions with relevant details of the project. If UAEAC feels that there is the prospect of purchasing goods from non-U.S. exporters, it should also approach the export credit agency of that country. Note that there is limited variance between the terms and conditions that these export credit agencies offer as they are governed by Berne Union Accord entered into by countries offering export credit agency financing.
5. When considering alternative financing structures, UAEAC should not only consider proposing a sovereign guaranteed structure, but also one that might offer risk mitigants (e.g. IATA receipts on behalf of the Government of Colombia) that could favorably improve the overall cost associated with borrowing. The structure should also reflect any strategy that the Government of Colombia might have on attracting foreign investment capital.
6. UAEAC should factor the prospect of procurement from more than one country of export origin and how that might affect the selection process for the source(s) of financing, including co-financing options.

3 FINANCIAL INSTITUTION LOAN PROCEDURES

3.1 IADB[5] Loan Review Cycle

The IADB project cycle consists of the following stages:

- **Preparation Phase:** The project cycle begins far before individual projects are conceived, with a collaborative process—called the programming process—between a country's government and IADB management that normally takes place every four to six years, depending on a country's electoral cycle. During the programming exercise, the country's government communicates its development priorities for the next several years to the Bank, identifying potential new initiatives by sector and financing instrument and reviewing the existing IADB portfolio.
- **Project approval: process and documents**: The preparation process culminates with the production and approval of a loan proposal or, for technical cooperation projects, a plan of operations. Environmental and social management reports, the logical framework for the project, and procurement plans are also made available at this time, either as part of the loan proposal or as stand-alone documents. Projects exceeding $750,000 (in IADB-administered financing) are approved by the Bank's Board of Executive Directors; projects with $750,000 or less in IADB-administered funding may be approved by the Bank's President, Country Office Representative or Regional Department Manager, depending on the amount and type of the project.
- **Implementation Phase:** During the implementation and supervision phase, consultants may be used for studies, training, and institutional strengthening; goods and equipment may be purchased, and civil works are carried out. While the borrower is wholly responsible for project implementation, including any procurement it entails, the Bank supervises the process to ensure that the project stays on schedule and that Bank procedures are followed in the procurement process. Usually, the Bank's Country Office in the borrowing country will supervise the project in accordance with the instructions contained in the loan proposal and the respective contract. The contract may describe the form and frequency of reviews of project implementation. The Bank disburses the loan as the project proceeds and the borrower incurs obligations relating to its implementation. Procurement plans are updated annually by the borrowers while projects are in implementation. General procurement notices and specific procurement notices are published on the IADB's Procurement Website, as required by the Bank's procurement procedures.
- **Completion and Evaluation Phase:** Evaluation activities are incorporated into every phase of the project cycle, beginning with the studies and impact analyses carried out during the preparation process and continuing until the project is completely implemented. Measures for improving the quality, reliability and transparency of the project cycle include project and sector analysis, specification of detailed project goals, indicators and procedures for monitoring, regular

[5] Source: IADB website www.iadb.org

examinations of projects halfway through their implementation, and impact evaluations. After a project has completed its implementation, the Bank's Country Offices and borrowers jointly produce project completion reports within three months following the end of project implementation. The Bank also prepares an Annual Report on Portfolio Management, Performance and Results for the Board of Executive Directors. Ex post evaluations may be also conducted at the request of the borrower after the project is completed. However, the Bank can decide to conduct its own project evaluation. Evaluations are utilized both as learning and planning tools by the country and the IADB during subsequent programming processes, as well as in the planning and development of future projects, both in the country and across the region.

3.2 World Bank Group (WBG) Loan Review Cycle[6]

- **The Identification Phase:** WBG's Country Assistance Strategy (CAS) forms the blueprint for its assistance to a country. In low-income countries, the CAS is based on the priorities identified in the country's Poverty Reduction Strategy Paper (as outlined above). The goals outlined in the CAS guide the priorities of the WBG's lending program and are a useful source of information for interested stakeholders and businesses wishing to identify potential future areas of WBG lending. During the identification phase, WBG teams work with the government to identify projects, which can be funded as part of the agreed development objectives. Once a project has been identified, the WBG team creates a Project Concept Note (PCN) which is an internal document of four to five pages that outlines the basic elements of the project, its proposed objective, likely risks, alternative scenarios to conducting the project, and a likely timetable for the project approval process.
- **The Preparation Phase:** This part of the process is driven by the country that WBG is working with and can take anything from a few months to three years, depending on the complexity of the project being proposed. WBG plays a supporting role, offering analysis and advice where requested. During this period, the technical, institutional, economic, environmental and financial issues facing the project will be studied and addressed - including whether there are alternative methods for achieving the same objectives. An assessment is required of projects proposed for WBG financing to help ensure that they are environmentally sound and sustainable (Environmental Assessment). The scope of the Environmental Assessment depends on the scope, scale and potential impact of the project.
- **The Appraisal Phase:** WBG is responsible for this part of the process. WBG's staff reviews the work done during identification and preparation, often spending three to four weeks in the client country. They prepare for WBG management either Project Appraisal Documents (investment projects) or Program Documents (for adjustment operations), and the Financial Management team assesses the financial aspects of the project. The PID is updated during this phase. These documents are released to the public after the project is approved (see below).

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[6] Source: www.worldbank.org

- **The Negotiation and Approval Phase:** After WBG staff members have appraised the proposed project, the WBG and the country that is seeking to borrow the funds negotiate on its final shape. Both sides come to an agreement on the terms and conditions of the loan. Then the Project Appraisal Document (PAD) or the Program Document (PGD), along with the Memorandum of the President and legal documents are submitted to WBG's Board of Executive Directors for approval. The appropriate documents are also submitted for final clearance by the borrowing government, which may involve ratification by a council of ministers or a country's legislature. Following approval by both parties, the loan agreement is formally signed by their representatives. Once this has occurred, the loan or credit is declared effective, or ready for disbursement, after the relevant conditions are met, and the agreement is made available to the public.
- **The Implementation and Supervision Phase:** The implementation of the project is the responsibility of the borrowing country, while WBG is responsible for supervision. Once the loan is approved, the borrowing government, with technical assistance from the WBG, prepares the specifications and evaluates bids for the procurement of goods and services for the project. WBG reviews this activity to ensure that its procurement guidelines have been followed. If they have, the funds will be disbursed. The WBG's Financial Management Team maintains an oversight of the financial management of the project including periodically requiring audited financial statements.
- **The Evaluation Phase:** Following the completion of a project, WBG's Operations Evaluation Department conducts an audit to measure its outcome against the original objectives. The audit entails a review of the project completion report and preparation of a separate report. Both reports are then submitted to the executive directors and the borrower. They are not released to the public.

Projects may be dropped at any point in the project cycle from preparation to approval. For these projects which never achieve active status, Project Information Documents, described above, are effectively the final documents.

3.3 Ex-Im Bank Application Process

- **How to Apply For Ex-Im Bank Financing**[7]
  1. Contact the Business Development Division (202-565-3946) for information about applying for Ex-Im Bank **export credit insurance** and **working capital guarantees.**
  2. You can apply for Ex-Im Bank financing for **medium- and long-term loans and guarantees** *using the Letter of Interest (LI) Application or the Preliminary Commitment (PC)/Final Commitment (AP) Application.* Apply for Ex-Im Bank financing when you have determined (1) that you are facing competition supported by foreign export credit agencies or (2) that financing

[7] Source: www.exim.gov

from the private sector is either unavailable or the amount and/or terms offered are inadequate to win the export sale. In most cases, either the LI or AP will be appropriate.

Note: The private banking sector plays a major role in facilitating U.S. exports by providing financial services independently and in conjunction with Ex-Im Bank. Ex-Im Bank encourages U.S. exporters to establish a relationship with a commercial financing institution.

- **Applying for a Letter of Interest**

The Letter of Interest (LI) is an indication of Ex-Im Bank's willingness to consider financing a given export transaction. Apply for an LI during the bidding or negotiating stage of an export sale when the following conditions exist:

- You need an indication from Ex-Im Bank on the general eligibility of the transaction participants and the goods and services to be exported.
- The repayment terms and other program guidelines in the LI provide you with specific enough guidance for your transaction.

An LI is generally issued within seven business days after Ex-Im Bank receives the application. The terms and conditions in the LI are valid for six months. At the request of the applicant, the LI can be renewed at six-month intervals, for up to two years. However, the terms are subject to change.

The review of the LI application includes comparing the transaction information to Ex-Im Bank's cover policy and identifying any potential issues that may need to be analyzed in more detail when an AP application is reviewed.

Any responsible party may apply for an LI. The applicant for an LI is usually the U.S. exporter or a financial advisor representing the exporter. A financial advisor acting on behalf of a foreign buyer may also apply for an LI, but the LI will be issued directly to the foreign buyer. A foreign buyer or borrower may also apply. The non-refundable processing fee for an LI is $100.

LIs are not available for credit guarantee facilities or exports of items to be used for nuclear power plants, nuclear fuel research reactors and related facilities. LIs are available for large aircraft transactions on a case-by-case basis (see Attachment A to the *LI Application*). Contact the Aircraft Finance Division (202-565-3550) for information concerning financing of large aircraft and ancillary equipment.

Ex-Im Bank offers a secure, Internet-based, online Letter of Interest Application. Applicants can submit, save and/or edit a LI application and make a credit card payment online. To apply online, go to the Ex-Im Bank website, **www.exim.gov** and select “LI Online” from the home page menu.

If you wish to pay by check or money order, complete the LI Application and return the signed original application, the required attachments and a check or money order made payable to the Export-Import Bank of the U.S. to:

Export-Import Bank of the U.S.
Attn: LI Applications
811 Vermont Avenue, N.W.
Washington, DC 20571

If you wish to pay by credit card, complete the *LI Application* and return the signed application with the required attachments and your credit card information either by mail or by fax to:

Export-Import Bank of the U.S.
Attn: LI Applications
Fax: (202-565-3380)

Note: LI Application Form can be found on the website listed above.

- **Applying for a Final Commitment**

The AP is an authorization of financing by Ex-Im Bank. Apply for an AP when the export contract has been awarded. Ex-Im Bank will perform a comprehensive evaluation of the transaction and any related issues. The AP will specify the exposure fee, which can be financed by Ex-Im Bank. It is not necessary to have an LI or PC before applying for an AP.

The applicant for an AP is responsible for payment of Ex-Im Bank's commitment fee for a loan or guarantee or facility fee for a credit guarantee facility. If the applicant is the lender, the lender may require the borrower to accept this responsibility in writing prior to submitting the AP application.

Only the foreign borrower may apply for an AP for an Ex-Im Bank direct loan. The foreign borrower or guaranteed lender may apply for an AP for a guarantee. If the lender has not been selected, only the borrower may apply for an AP for a guarantee. In cases where the borrower is a special purpose vehicle, the applicant must be the guarantor, if there is one. If there is no guarantor, the applicant must be the company obligated to make payments to the special purpose vehicle.

While the *PC/AP Application* is used to apply for limited recourse project financing, other types of financing commitments are offered and a separate fee arrangement applies. Please contact the Ex-Im Bank Structured and Project Finance Division (202-565-3690) for more information on the specific types of financing commitments offered for limited recourse project financing and the relevant application processing fees.

- **Where to Apply for a Final Commitment**

  Complete the *AP Application* and mail the signed original application, and the required attachments to:

  > **Export-Import Bank of the U.S.**
  > Attn: Credit Applications and Processing
  > 811 Vermont Avenue, N.W.
  > Washington, D.C. 20571

- **Applying for a Preliminary Commitment**

  The PC is an offer of Ex-Im Bank financing subject to the award of the export contract and Ex-Im Bank's review of an AP application. Ex-Im Bank reserves the right to determine when a request for a PC is justified and has established the following three criteria for the appropriate use of a PC.

  - If the award of the export contract is subject to a formal competitive bid process in which there is clear evidence that an actual quote of the definitive rates, fees, terms, and conditions of Ex-Im Bank support must be presented, then Ex-Im Bank will accept an application for a PC.
  - If the exports are items to be used for nuclear power plants, nuclear fuel research reactors and related facilities, Ex-Im Bank will require a PC application. An LI is not available.
  - If the applicant requests resolution of significant financial, technical, environmental, or policy issues which would have a critical impact on the availability of Ex-Im Bank support, Ex-Im Bank will accept an application for a PC only if it determines that the issues are significant enough to warrant Ex-Im Bank's review prior to the award of the export contract.

In order for Ex-Im Bank to perform the necessary review of program and credit issues required to issue a PC and specify an exposure fee, the *PC/AP Application* requires more detailed information pertaining to the transaction than the *LI Application.* Examples of case-specific issues include: economic impact on U.S. production; eligibility of military-related products; environmental impact of the project; and credit review of the borrower (and guarantor, if any). Ex-Im Bank will issue a PC subject to final review of outstanding issues when information is not available at the PC stage. However, Ex-Im Bank will require sufficient information on the borrower (and guarantor, if any) in order to establish a specific exposure fee.

The applicant has two PC options: a four-month PC with a cap on Ex-Im Bank's direct loan interest rate or a six-month PC with no interest rate cap. The terms and conditions of the PC are valid for four months or six months, depending on the option selected. At the request of the applicant, the PC can be renewed at four-month or six-month intervals, but the terms are subject to change. Large aircraft transactions are not eligible for the four-month PC option with the interest rate cap. All PCs for large aircraft transactions will continue to be valid for six months and can be renewed at six-month intervals, but the terms are subject to change. PCs are not available for credit guarantee facilities.

Any responsible party may apply for a PC. The applicant for a PC is usually the U.S. exporter or a financial advisor representing the exporter. A foreign buyer or borrower may also apply for a PC.

The processing fee for a PC is equivalent to 1/10 of one percent of the requested amount of the financing (excluding the exposure fee), up to a maximum of $25,000. If the foreign buyer or borrower applies for a PC, the processing fee may be paid by the U.S. exporter. This fee will be rebated if and when an AP is approved by Ex-Im Bank.

The higher processing fee for the PC is intended to cover the additional transaction processing costs associated with issuing a PC and to encourage appropriate use of the LI. Exceptionally, if the Board approves a PC with a tied aid offer, Ex-Im Bank will immediately refund the PC processing fee regardless of whether the exporter eventually wins or loses the export contract.

- **Where to Apply for a Preliminary Commitment**
  Complete the *PC Application* and mail the signed original application, the required attachments and a check or money order made payable to the Export-Import Bank of the U.S. to:

  Export-Import Bank of the U.S.
  Attn: Credit Applications and Processing
  811 Vermont Avenue, N.W.
  Washington, DC 20571