DAY FOUR

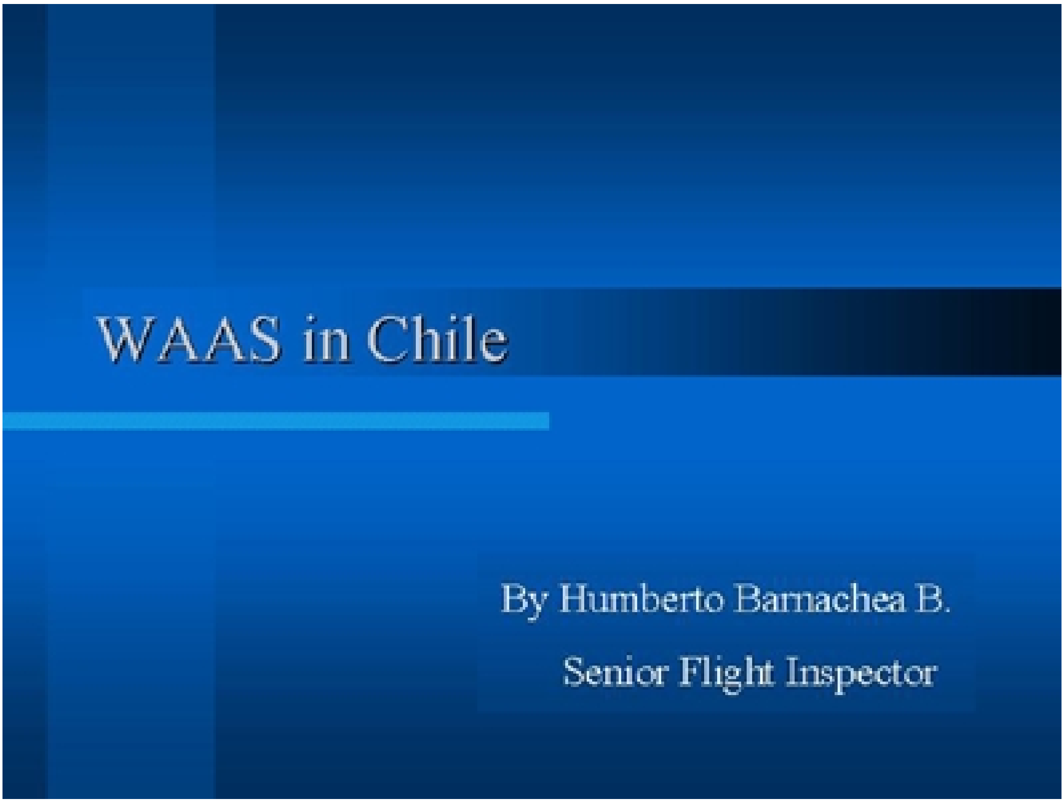
GNSS FLIGHT INSPECTION

FINANCIAL AND ORGANIZATIONAL ASPECTS

CLOSING

FRIDAY - JUNE 9, 2000


INSPECCION EN VUELO
CHILE
Flight Inspection Group
Chile


WAAS in Chile
By Humberto Barnachea B.
Senior Flight Inspector

FAA OFFICE OF PUBLIC AFFAIRS

PRESS RELEASES HTTP://WWW.FAA.GOV/APA/PR

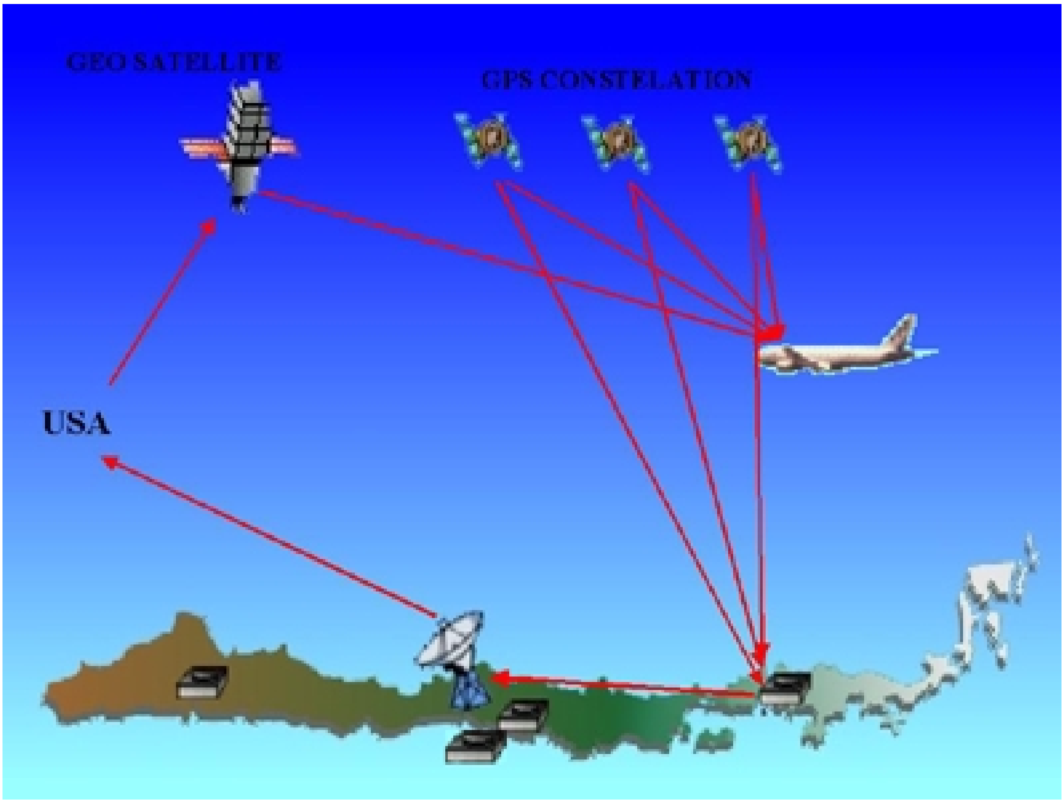
800 INDEPENDENCE AVE., WASHINGTON D.C., 20591

FAA Completes Successful WAAS Flight Trials in the Republic of Chile

WASHINGTON - The Federal Aviation Administration (FAA) and the Republic of Chile's Director General of Civil Aeronautics (DGAC) successfully completed the first test flights in Chile demonstrating the capabilities and benefits of the Wide Area Augmentation System (WAAS).

The test flights were conducted at the Arturo Merino Benitez International Airport in Santiago, Chile, on Dec. 9. This effort represents the latest step towards achieving a seamless, worldwide satellite-based air navigation system. WAAS consists of a network of differential Global Positioning System (GPS) ground stations that receive, analyze and provide corrections to signals from GPS satellites, and transmit that information to aircraft flying within the WAAS coverage area.

"These successful flight trials achieved another major step toward the establishment of a safer and more dependable satellite-based air navigation system for North and South America," said FAA Administrator Jane F. Garvey.


GEO SATELLITE
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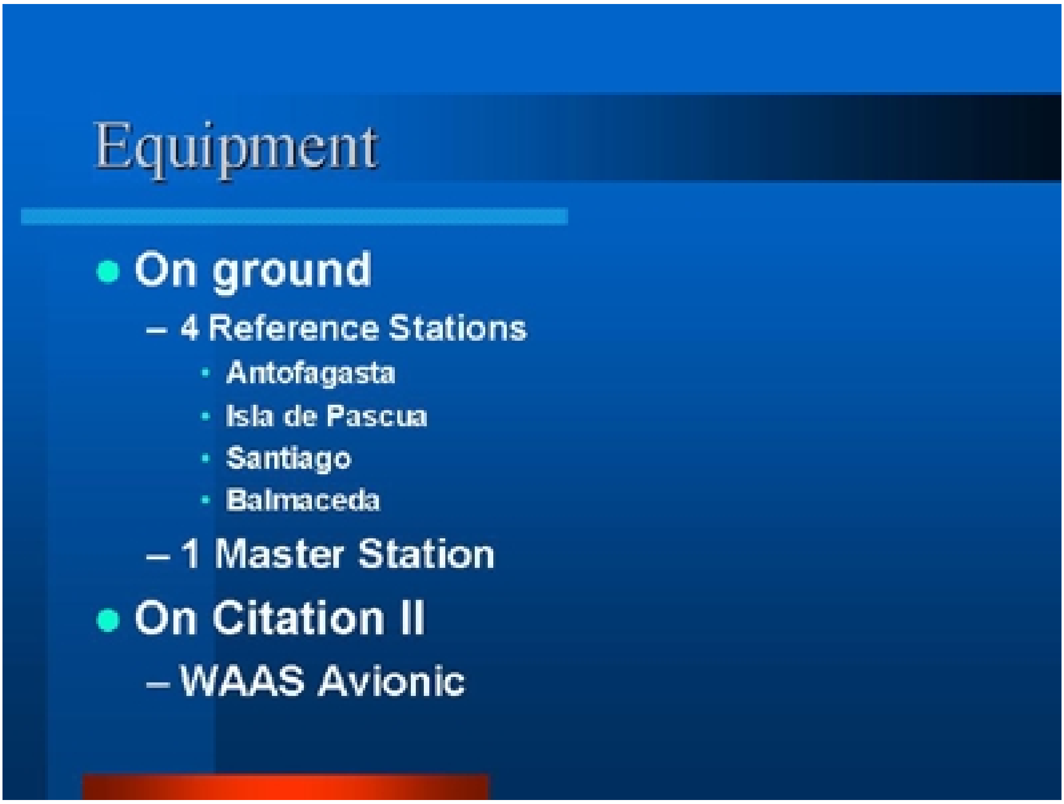
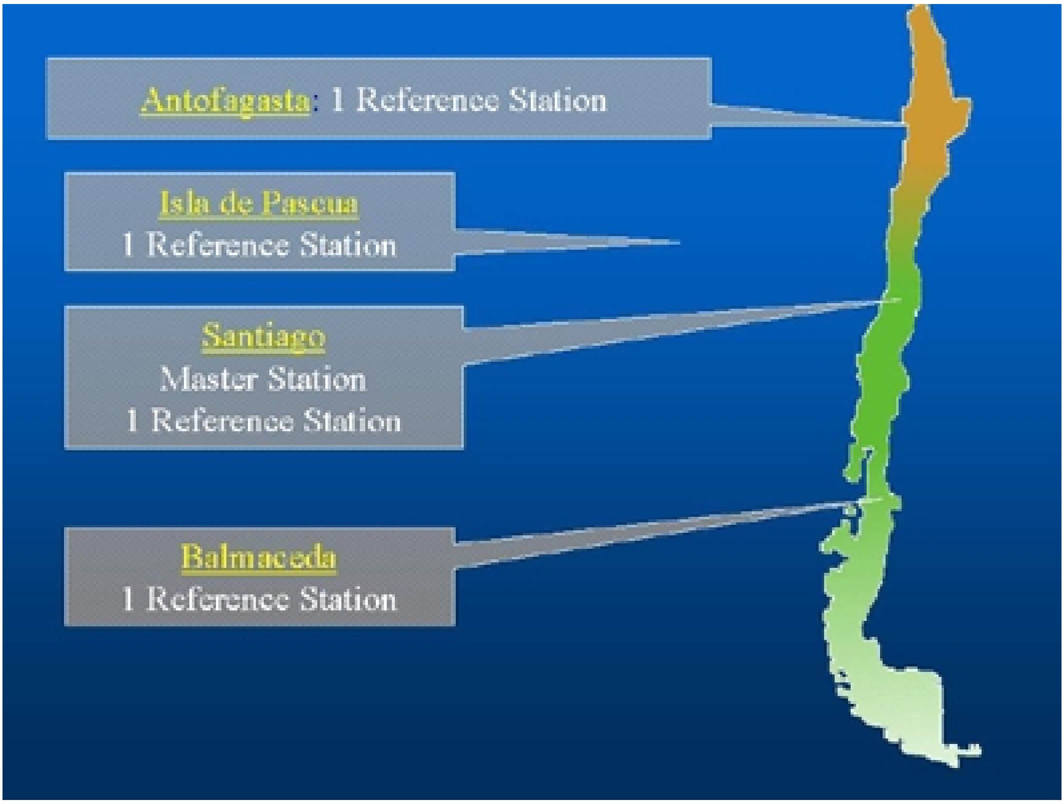
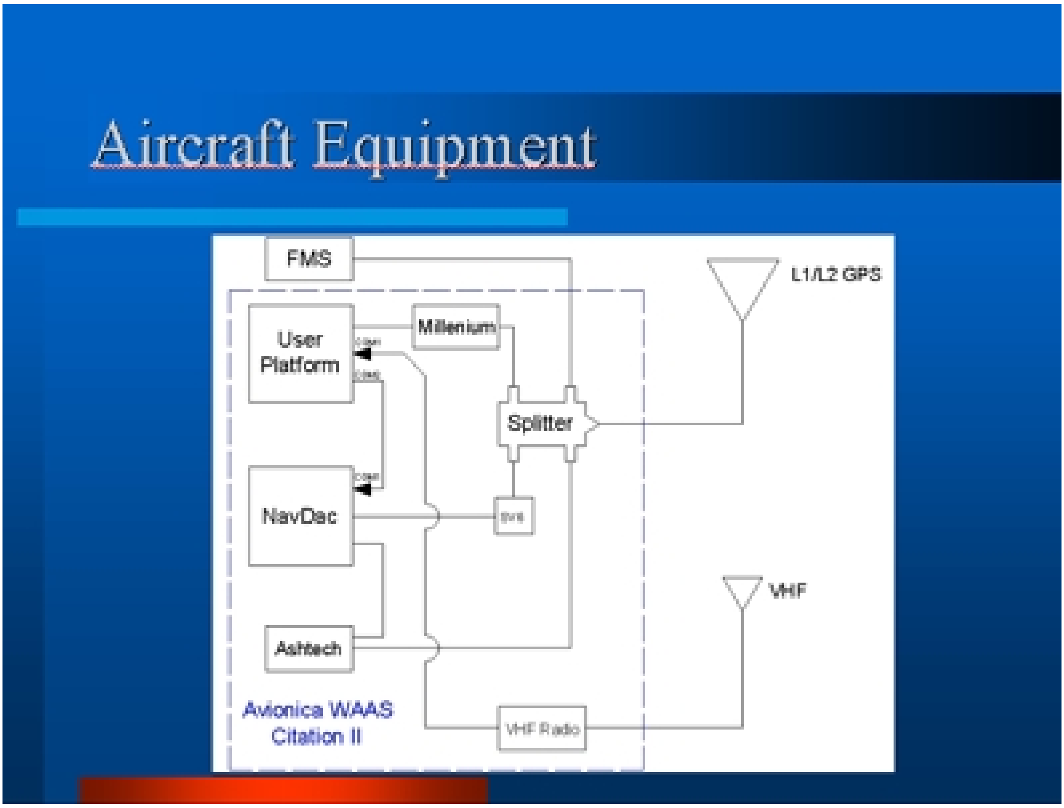

Equipment
On ground
– 4 Reference Stations
Antofagasta
Isla de Pascua
Santiago
Balmaceda
– 1 Master Station
On Citation II
– WAAS Avionic



Antofagasta: 1 Reference Station
Isla de Pascua
1 Reference Station
Santiago
Master Station
1 Reference Station
Balmaceda
1 Reference Station



Aircraft Equipment
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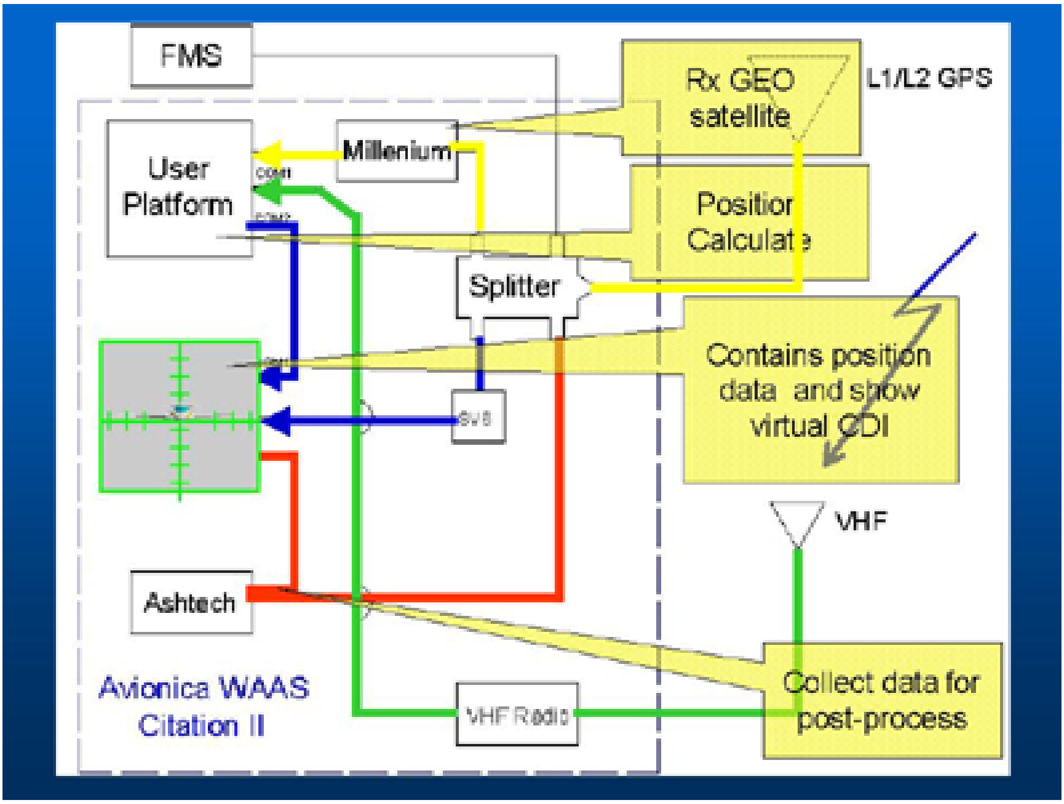
User Platform
Millenium
Splitter
NavDac
VHF
Ashtech
Avionica WAAS
Citation II
VHF Radio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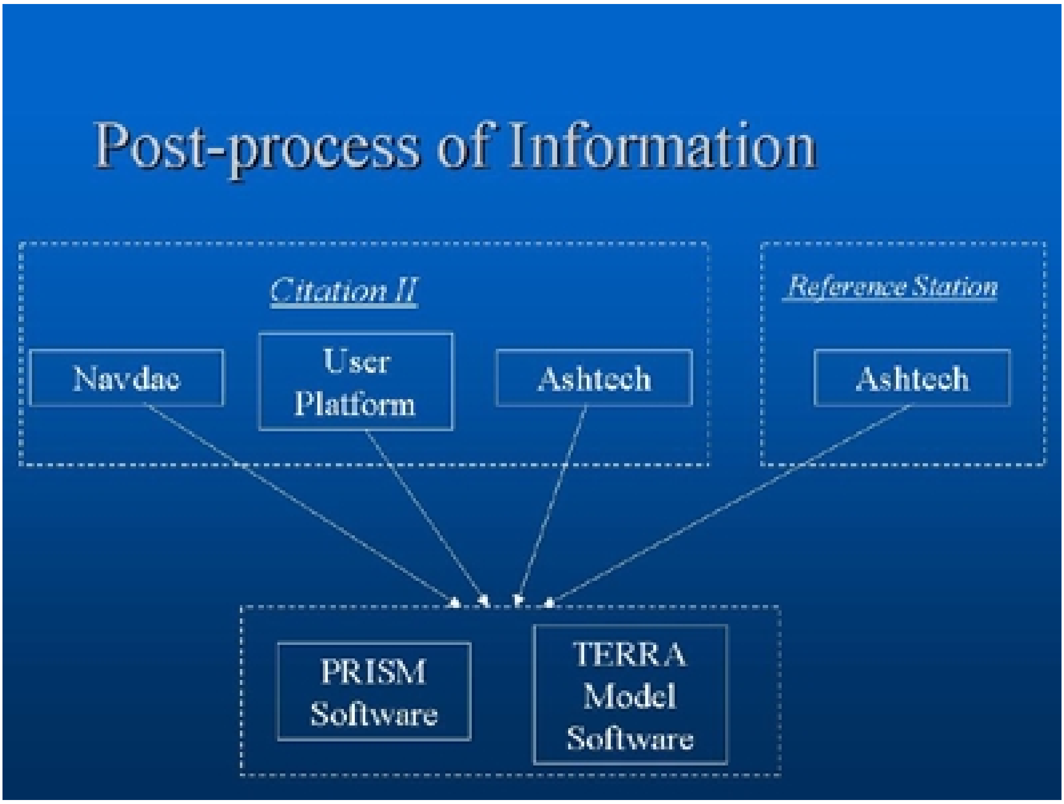
Rx GEO satellite
L1/L2 GPS
User Platform
Millenium
Position Calculate
Splitter
Contains position data and show virtual CDI
VHF
Ashtech
Avionica WAAS Citation II
VHF Radio
Collect data for post-process


Post-process of Information
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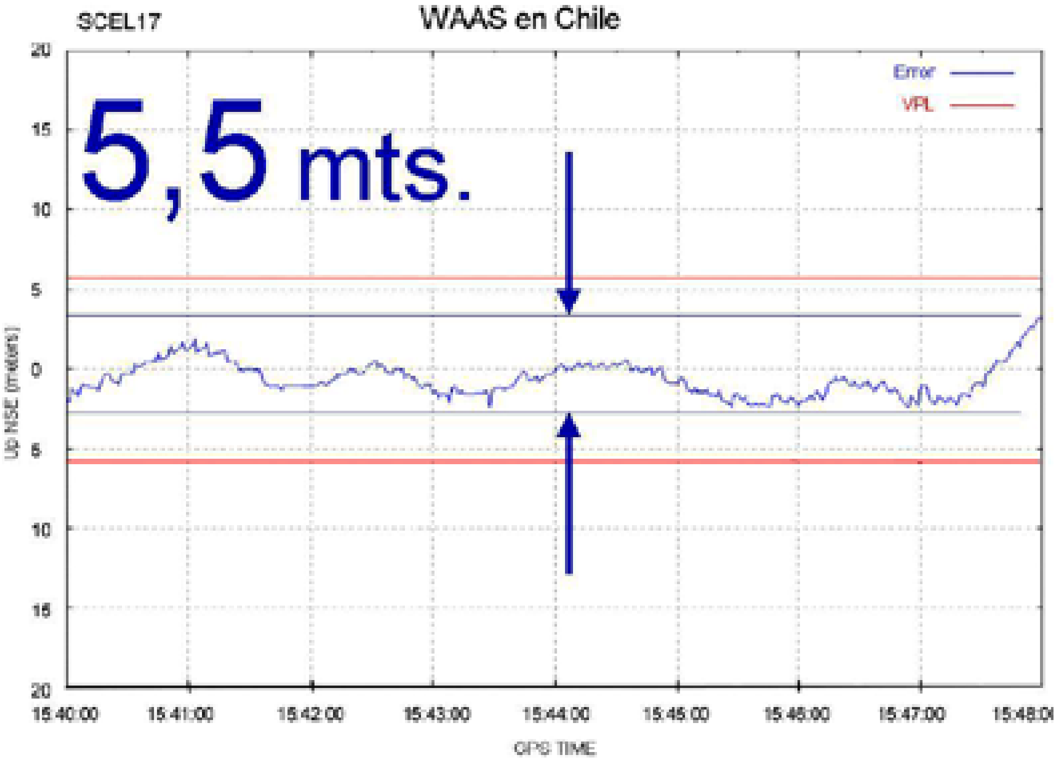
Reference Station
Navdac
User Platform
Ashtech
Ashtech
PRISM Software
TERRA Model Software


SCEL17
WAAS en Chile
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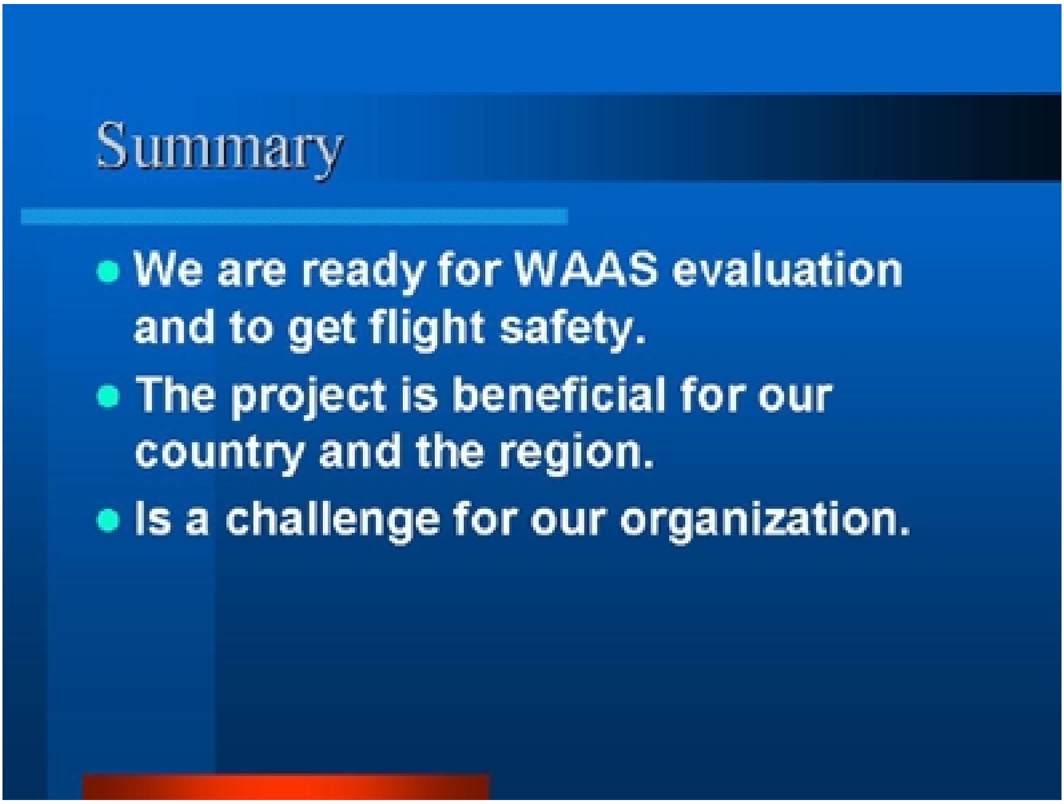
GPS TIME


Summary
We are ready for WAAS evaluation and to get flight safety.
The project is beneficial for our country and the region.
Is a challenge for our organization.

Robert Loh and Jason Nelson
Innovative Solutions International (ISI)
1608 Spring Hill Road, Suite 200
Vienna, VA 22182, U.S.A.

FLIGHT INSPECTION OF REGIONAL GPS SATELLITE BASED AUGMENTATTION SYSTEMS (SBAS) - ISSUES AND CONCERNS

ABSTRACT

The United States had offered and the International Civil Aviation Organization (ICAO) has accepted the Global Positioning System (GPS) satellites as part of an initial component of a worldwide Global Navigation Satellite System (GNSS). The current implementation of the GPS does not satisfy all the requirements of a sole means aviation system for navigation and landing worldwide. Therefore, many countries are in the process of testing or implementing a GPS satellite based augmentation system (SBAS) to improve the performance and availability of the GPS for satellite navigation and landing. However, these regional or national systems are being developed simultaneously without an existing international standard so that there are no guarantees that they will be fully interoperable, or have the same performance levels. While interoperability is an objective of all the SBAS developers, they may only be partially successful, especially during the initial phases of implementation. Therefore, local civil aviation authorities (CAA) have to be aware of those differences and account for them during their approval and flight inspections. This paper will provide an overview of the different SBASs under development, and how they can expand and grow into systems that will cover the whole world. A brief discussion will be provided to address the issues and concerns of fight inspections for generic satellite based navigation systems, followed by the specific issues and concerns that are unique to the operational implementation of SBASs worldwide, and their approvals for national airspace.

INTRODUCTION

In the US, the Federal Aviation Administration (FAA) is in the process of implementing the Wide Area Augmentation System (WAAS); in Europe, the Tripartite (composed of the European Commission, Eurocontrol, and the European Space Agency) are implementing the European Geostationary Navigation Overlay System (EGNOS); in Japan, the Civil Aviation Bureau of Japan (JCAB) is implementing the MTSAT-Based Augmentation System (MSAS); and in Canada and Australia, they are testing various components of an SBAS in order to verify the feasibility of SBAS in their countries.

Cooperation and coordination to standardize the different SBAS are in progress with ICAO, Requirements and Technical Concepts (RTCA), and European Organization for Civil Aviation Equipment (EUROCAE) leading the efforts to standardize the signal-in-space formats so that SBAS/GPS receivers can use all the signals from the different systems. However, not many countries can afford or need their own independent SBAS or a complete SBAS. Therefore, different countries will have to cooperate, share and contribute different SBAS components and resources towards a complete SBAS. Even for the US, Europe, and Japan, inter-system cooperation and coordination within the different SBASs will improve performance, reduce costs and make the individual SBASs more efficient and effective. This paper will present the different technical, operational, and regulatory issues and concerns that will have to be addressed by the national civil aviation authorities and specifically the flight inspection personnel so that the different SBASs can be used seamlessly by the civil aviation community worldwide. Up to now, most of the satellite navigation flight inspection activities have been concentrated on the development of GPS for operational use from en route, through terminal, and down to non-precision approach procedures. But within a couple of years, there may be several different SBASs that will be certified for operational use in those similar airspace. These SBASs will provide navigation messages that will improve the performance of the GPS satellites worldwide.

The SBAS ground reference stations will collect the GPS satellite data, remove any GPS satellite errors (including any Selective Availability (SA) degradations, if they are turned on again) and transmit the GPS augmentation messages through SBAS geostationary satellites. The broadcast from the geostationary satellites will cover the entire world with GPS satellite corrections. In many places around the world there will be dual or triple redundant coverage by the different SBASs. Over the United States, Japan, and Europe, the SBAS correction messages can improve the performance of GPS and satellite navigation from a horizontal accuracy of 100 meters (with SA) and 20 to 30 meters without SA to a horizontal accuracy of less than 5 meters. For integrity, the SBASs will provide an integrity signal that will notify users, within 10 seconds, when GPS satellites have failed and cannot be used for navigation. In addition, the SBAS satellites themselves can be used as another ranging source for position determination so that the worldwide satellite navigation system will in the future consist of 24 GPS satellites and at least 5 SBAS geostationary satellites. This will occur with the implementation of the first three SBASs mentioned above, and in the future there will be additional SBAS satellites. Therefore, availability will also improve significantly with the implementation of the SBASs. For users worldwide, the SBAS corrections can also be used anywhere in the world even at locations where there are no SBAS ground reference stations. The SBAS systems will remove the remaining GPS satellite clock errors and GPS satellite ephemeris errors for all users worldwide.

SATELLITE BASED AUGMENTATION SYSTEMS (SBAS)

Wide Area Augmentation System (WAAS)

The FAA is implementing the WAAS to augment the GPS to improve integrity, accuracy, availability, and continuity of satellite navigation so that it can be used for all phases of flight from oceanic down to Cat I precision approaches. The phase I WAAS will consist of 25 ground reference stations all connected together by a communications system to two ground master stations. The master stations are then connected to four ground earth stations which broadcast the WAAS messages through the two geostationary Inmarsat satellite transponders. The WAAS messages from the Inmarsat transponders are modulated on the same frequency as the GPS satellites (GPS L1 frequency) so that user antennas and receiver front ends are the same as for the GPS signals. This should significantly reduce the WAAS implementation costs for users that are already equipped with GPS antennas and receivers. The FAA began a very aggressive satellite navigation program in 1992, starting with the GPS, and then moving onto augmentation systems. The current WAAS program should result in an operational capability in 2002, and many other nations are expected to join the WAAS in the future.

European Geostationary Navigation Overlay System (EGNOS)

In 1995, the European Tripartite Group (ETG) made up of the European Commission (EC), Eurocontrol, and the European Space Agency (ESA), agreed to collaborate on a joint program that would represent Europe’s contribution to a GNSS. The joint program is called EGNOS, which will be operational sometime in 2003. The objective of EGNOS is to enhance the performance of GPS and the Russian satellite navigation system called GLONASS. Three functions were proposed for EGNOS, a ranging function, an integrity function, and a differential function. Based on the current plans, EGNOS will initially have more reference stations than the WAAS, more master stations than the WAAS, and more geostationary satellite transponders than the phase I WAAS.

Multifunctional Transport Satellite (MTSAT) Satellite Augmentation System (MSAS)

The Japanese government is implementing the MTSAT for both the Japanese Civil Aviation Bureau (JCAB) and the Japanese Meteorological Agency (JMA). The JCAB will be responsible for the aeronautical mission, which includes air traffic control communications, automatic dependent surveillance (ADS), and a SBAS transponder. In addition to MTSAT, the JCAB is also implementing the MSAS, which will enhance the GPS accuracy, integrity, availability, and continuity similar to the WAAS. The MSAS is also a multi-phased system with phase I beginning in 2003. This initial phase will include 8 reference stations, two master stations, and one geostationary satellite transponder.

GROWTH OF SBASs INTO A WORLDWIDE SYSTEM

Within a couple of years the three SBASs under development are expected to be implemented for worldwide use. Soon afterwards, Canada, Mexico, South America, and several other nations are also expected to implement SBAS systems. However, many countries can not afford, nor do they need, their own independent SBAS or a complete SBAS. These countries can cooperate, share and contribute different SBAS components and resources towards an existing SBAS or build their own regional SBAS. The three SBASs being implemented by the different governments have been designed as global systems. Therefore, they can accommodate different components of a SBAS that have been developed by other countries, and together grow into a complete worldwide system. Any country, large or small, need only build the SBAS components that are necessary for navigation, landing, and control over its own airspace; these different SBAS components can then be integrated into a much larger worldwide system.

Levels of Participation in a SBAS

At least four distinct levels of participation in a SBAS can be implemented, depending on a nation's or region's needs and ability to fund SBAS components.

- Level 1 requires no separate funding by the independent nation; however, suitably equipped aircraft flying over its airspace can still use a nearby SBAS and obtain benefits from integrity signals, reduction in satellite clock and ephemeris errors.

- Level 2 requires the independent nation to install a reference station and connect it to a master station in another country. This will provide the nation with additional benefits, such as additional satellites that will be visible from the reference station. The improvements from this reference station may provide Category I (CAT I) precision approaches at some locations within the nation.

- Level 3 requires the independent nation to install reference stations at all key locations to make the SBAS signals valid and available throughout the nation. Level 3 will require a larger budget, but the SBAS signals will provide sufficient accuracy for Category I precision approaches throughout the nation. All the reference stations would be connected to at least one master station in another country.

- Level 4 requires a significant increase in cost for an independent nation, because it will require the deployment of a master station to consolidate the information from all the reference stations within the nation. The consolidated information will be sent to another master station in another country for broadcast through the SBAS transponder on a geostationary satellite. This would provide almost total control for the nation.

The different levels of participation in space-based augmentation is dependent on a nation's needs and resources. But the levels only refer to a single host

SBAS, and not how different SBAS hosts can be used together. WAAS, EGNOS, and MSAS are different and independent SBAS hosts, and have different and independent SBAS transponders on different geostationary satellites. The separate SBAS signals in space, however, are still part of an overall worldwide system design, so that all regional or national SBAS signals should be able to be used by the same receiver in the aircraft flying worldwide. These national and regional infrastructures should all contribute to a seamless worldwide SBAS network, allowing a suitably equipped aircraft to fly worldwide and to receive signals with a common message structure to improve integrity, accuracy, and availability of GPS. In addition, each independent nation retains some level of control over the use of the SBAS and GPS over its sovereign airspace.

GENERAL CONSIDERATIONS FOR FLIGHT INSPECTION OF SATELLITE NAVIGATION SYSTEMS

Flight inspection will still be needed for satellite navigation systems because of similar concerns as the traditional ground based navigation systems such as variable site conditions, ground connectivity changes, terrain irregularities, metallic structures, power lines, and certain propagation aberrations that may adversely affect the signal received by the user aircraft. Additionally, the increase of AM and FM radio stations, cellular phones, computerized industrial equipment, and other sources of potential spurious radiation may also affect satellite navigation users. This will require flight inspections to verify that any potential interference sources will not have any operational impact on the users of satellite navigation.

For approach procedures based on satellite navigation, there is no longer a single point, static position reference upon which the aircraft can rely for information. The availability of accurate positioning information is not based on distance from or angle of elevation above the site, but on the number of satellites available and the relative geometry of each satellite to the aircraft. The satellites are constantly moving as they orbit the earth, so that accuracy obtained from any four satellites could be different when another set of four satellites is used during flight inspection of the same procedure four hours later.

Accurate positioning of the aircraft is only part of the problem in flying a satellite navigation system. The receiver or flight management system must know the precise geographic coordinates on which the procedure is based in order to provide accurate guidance throughout the procedure. Confirmation that these coordinates are correct and reflect the flight profile as depicted in the procedure can only be verified by actually flying the procedure and measuring the track deviation throughout the flight profile.

For the traditional ground based navigation system, coverage is normally a problem at long distances and low altitudes relative to the site. For approaches based on satellite navigation, the problem is more likely to occur at the most critical stage of the procedure, namely at low altitude during the final approach portion of the procedure. At these low altitudes, the chance of terrain masking of the signal from the individual satellites is the highest. Although terrain simulation computer programs can alert a procedure designer to the potential for this problem, a flight evaluation of the procedure should be carried out to ensure that there are no operational limitations due to the reduction in the line of sight horizon.

Since satellites cannot be adjusted, the actual performance at the alarm limits cannot be tested during flight inspection. Banking of the aircraft may also have to be performed during flight inspection but for different reasons than that used for ILS flight inspections. For a SBAS system, where the correction broadcast is from a geostationary satellite, banking tests may be needed to verify the coverage during turns performed as part of the approach procedure.

SPECIFIC ISSUES AND CONCERNS FOR FLIGHT INSPECTION OF SBASs

The specific issues and concerns for the flight inspection of different SBASs implemented by different CAAs around the world will be discussed in this part of the paper. The challenge is to be able to verify with flight inspection that the SBASs implemented by the different organizations worldwide are seamless and integrated for users in the national airspace. The discussions of issues and concerns for flight inspection will be separated into two sections, one that involve the technical aspects of the interoperability of SBASs, and another that involve the operational and regulatory aspects of SBASs for users in the national airpace.

Technical Aspects of Implementing SBASs for National Use

There are several stages of technical interoperability between two independent SBASs. The minimum prerequisite for interoperability is that an aircraft be able to fly between two or more SBASs using the same avionics and experience a smooth, seamless transition. This means that the signals in space are sufficiently compatible to allow the same avionics to receive and process both SBAS signals.

The different stages of interoperability are described below in increasing degrees of connectivity and interoperability, which can be associated with increasing levels of effort towards interfacing, coordination, and standardization between the SBASs.

Interoperability Stage 1 — The first and minimum stage of interoperability between SBASs is a guarantee that the same user avionics can receive and use both signals, and that the transition between the two is seamless. At this stage, it is only necessary to ensure that both signal formats are consistent with each other and that the avionics can distinguish which data fields to apply for which SBAS. If the transition between the two systems occurs over the ocean, the corrections may be slightly different, as long as the difference can be bridged smoothly and be completed before the aircraft enters any domestic airspace.

ICAO, through the Global Navigation Satellite System Panel (GNSSP), Requirements and Technical Concepts for Aviation (RTCA), and the European Organization for Civil Aviation Equipment (EUROCAE), are all working hard to ensure that this minimum stage of interoperability exists. The FAA is also working on this issue with other Civil Aviation Authorities (CAAs) to ensure that everyone can benefit from this level of interoperability. The FAA, ETG, and the JCAB have been meeting regularly as part of the Interoperability Working Group (IWG) to ensure the three SBASs are interoperable.

The FAA has set up National Satellite Test Bed (NSTB) stations in Alaska and Hawaii to act as separate WAAS systems so that their interface can be analyzed and developed. The FAA is also working with the Japanese Civil Aviation Bureau (JCAB) to ensure that the MSAS and WAAS will be interoperable. In addition, the FAA is working with Europe on an Interface Control Document (ICD) between the different SBASs, and is testing the interoperability between the two systems in Iceland. The FAA will also have operational experience and data on interoperability when Canada joins the WAAS. Only after operational experiences and data are collected can the FAA and other CAAs verify that separate systems can be completely integrated. However, the benefit of stage one is that minimum coordination is required between the different SBAS developers.

Interoperability Stage 2 — The second stage of interoperability will ensure that the signal format between the two systems are exactly the same, so that user avionics are simplified. This is the first step towards a more complete, worldwide, seamless system. The use of the same format will reduce the time for certification of avionics and allow manufacturers in any country to build certified receivers for users in all countries. The same transition issues as in stage 1 also apply; i.e., if the transition between two systems will occur over the ocean, the corrections may be slightly different, as long as the difference can be bridged smoothly and be completed before the aircraft enters any domestic airspace. In this second stage of interoperability, transition is simplified, since the same signal format is used. The first two stages of interoperability require no connectivity between the systems.

Interoperability Stage 3 — The third stage of interoperability requires the interchange of data between the different SBASs. A connection is made between two master stations. The easiest type of data to exchange is information on the integrity of satellites that are not visible to the other system, so that rising satellites can be used more quickly by the users and setting satellites can be used for a longer period of time. Therefore, integrity on the satellites can be provided by either system, and receivers will be able to use satellites that are seen by several SBASs. The same transition issues as in the first two stages still apply. None of the first three stages can guarantee that the corrections from the different SBASs will be correlated closely enough for approaches. The accuracy may be sufficient, but the differences between the corrections data may cause a large transient jump when going from one SBAS to another, making them unsuitable for use during transition.

Other data exchanges that are possible for this stage of interoperability include the exchange of ionospheric data that will help in the prediction of the occurrence and strength of the impact of solar storms. The ionosphere is a major, albeit correctable, source of error for SBASs. Orbit information and satellite clock errors are also useful information which will help SBASs determine the corrections of a rising satellite earlier. Finally, and most importantly, timing information to support synchronization can also be exchanged between systems so that the offset between them can be reduced and the transitions between them can be further smoothed.

However, details on the types of information that are needed for the interface and the utility of the data exchange still need to be analyzed. These issues are complex, and some operational experience with SBASs, as well as tests and verification on systems such as the NSTB, will be necessary before they are all resolved. Therefore, these studies will proceed as the initial SBASs become operational. Transition problems will be reduced at this stage of interoperability, since each has data from the other, and can approximately determine how corrections for both systems are calculated.

Interoperability Stage 4 — The fourth stage of interoperability requires that data from the reference stations be integrated into another system. This means that data from a RMS in one SBAS will be used by the master station of another SBAS. This data sharing can result in substantial cost savings for both systems. For a particular SBAS, the information from many foreign RMSs can be used to improve orbit determination for both that particular SBAS and GPS in general, and vice versa. In addition, when one RMS fails, the RMS from another SBAS can be used to satisfy redundancy requirements. For example, in the US WAAS, fewer stations may be required for Alaska and Hawaii if data from MSAS RMSs can be used. However, to accomplish this, the RMSs must have similar hardware and software so that the data can be completely integrated and certified between them, and the integrity of the data can be verified. Interoperability and integration will be further facilitated if all the critical elements, such as safety-related hardware and software, of both SBASs are identical. Additional studies and analyses will be necessary to determine whether complete integration is possible if the reference stations do not have identical hardware and software.

If the software and hardware at the master stations are not the same, then the transition between the systems may still be difficult, even if both systems are using the same RMSs and the same data set. However, two SBASs can still be highly integrated for some aspects of their operations, even if they have different hardware and software for applications that are not safety-related, such as non-critical operations and maintenance software and hardware.

Interoperability Stage 5 — The fifth stage of interoperability requires that the two systems are completely integrated and identical, so that the master station(s) and RMSs of one SBAS can back-up the master station(s) and RMSs of the other. This requires that all the critical elements of both systems are the same, so that they are truly redundant. It implies that all safety related hardware and software are identical and are certified to the same levels. This stage of interoperability will provide substantial cost savings to both countries, as fewer stations and resources are needed to satisfy the sole-means requirements for civil aviation in their respective Flight Information Regions (FIRs). This will provide a significant step towards the objective of a seamless, global, integrated system. On the negative side, this level of interoperability will require an additional communication backbone line to provide redundancy to another backbone node in the communications network. As an example, the implementation of the WAAS in Canada will be at this interoperability stage, where Canada may implement many WAAS Reference Stations (WRSs) and one master station, which can be used as a backup to a master station in the US.

Besides the interoperability of the SBASs, the coverage and performance of each SBAS is normally predicted by computer models called service volume model (SVM). Therefore, the SVMs will also have to be compatible so that the coverage and performance predicted by the SVM of one SBAS developer is equivalent or very similar to another SVM that has been developed and is being used by another SBAS developer. It is anticipated that flight inspection will have to verify that the service volume and performance of the SBASs in various national airspace, such as in the en route airspace, are as specified by the SVMs.

Operational and Regulatory Aspects of Implementing SBASs for National Use

It is also very important that the airborne receiver manufacturers adopt standards developed by RTCA, EUROCAE, and ICAO. In the proposed design concept, the avionics are able to receive signals from multiple SBASs and can switch from one to another. Currently, only RTCA has a proposed signal format for the SBASs, and it is anticipated that both EUROCAE and ICAO will adopt the same or similar format.

Three areas of avionics standards must be addressed: certification and approval for the use of different SBASs, rules for prioritizing signals when several are available, and standards for transitioning from one SBAS to another. It is anticipated that the corrections from the different SBASs will not be identical, and that the user avionics will have to make the transition between the two SBASs using a smoothing algorithm. Based on international standards, the aircraft's receiver must decide if it can (1) use both or more signals, (2) select one, or (3) use both or more with one as the primary and the others prioritized as the secondary signals. The continuity of operations and the transition from one system to another must also be based on strict rules and regulations that have to be standardized by RTCA, EUROCAE, and ICAO. But first, the CAA responsible for air traffic control (ATC) in a FIR must have established how adjacent SBASs can be certified for use in the FIR.

Use of the signal information for an adjacent SBAS can be approved and certified at the four application levels as described below:

Application Level 1 — Use adjacent SBAS as a ranging signal with no guarantee on its integrity and accuracy
Application Level 2 — Use adjacent SBAS as a ranging signal, and its integrity information on the GPS and SBAS satellites are approved and certified
Application Level 3 — Use adjacent SBAS as a ranging signal; its integrity information on GPS and SBAS satellites are approved and certified, and its fast and slow corrections can also be applied and used in the FIR
Application Level 4 — Use adjacent SBAS as a ranging signal; its integrity information on GPS and SBAS satellites are approved and certified, its fast and slow corrections can be applied and used in the FIR, and its ionospheric grid data is also certified

and can be used for precision approaches

Unless all RMSs of a SBAS are interconnected to the other systems' master stations, the CAAs will probably only approve or certify the use of an adjacent SBAS up to Application Level 3, where the corrections from both systems can be used by the avionics. If two SBASs have the same critical hardware and software, then it will be easier for both to approve that level of application.

The second area that needs to be addressed is the requirement for priority rules when different SBASs are available for use. There should be a set of standards for the avionics that detail how the different SBAS signal-in-space (SIS) are selected and used if signals from more than one system are available in a given area.

The following rules are examples of what should be embedded in the user receiver, along with the recommended priority for selecting the primary SBAS signal:

SIS Priority 1 — A CAA requires that a specific SBAS signal be used in their controlled FIR.
SIS Priority 2 — When more than one SBAS signal is approved for an FIR, a primary SBAS must be defined by the controlling CAA. The primary and secondary SBASs for each area of flight is then pre-defined and can be selected as part of the flight planning process.
SIS Priority 3 — The SBAS signal that provides ionospheric grid corrections should be selected by the receiver over one that does not provide the ionospheric corrections.
SIS Priority 4 — The SBAS that provides the correction signal for a GPS satellite that is seen at a higher elevation angle than another SBAS viewing the same GPS satellite.

The third area is standardizing receivers to transition from one SBAS to another. In order to make the transition, receivers must be able to:

* Process corrections signals from both SBASs for a period of time before transitioning from one system to another. Since the two SBASs will not be receiving identical data, the fast and slow corrections from both will be slightly different.
* Process FIR map data in order to match coverage of the controlling SBAS as defined by the controlling CAA.
* Select one SBAS as primary SBAS based on the SIS Priority Rules.
* Process all SBAS signals for use in a Receiver Autonomous Integrity Monitoring (RAIM)/Fault Detection and Exclusion (FDE) mode of navigation.
* Select only one SBAS as primary for corrections data and ionospheric grid delays if available.

Example of A Future Flight Using SBASs

In the first phases of any SBAS implementation, there probably will be no physical connection between the different SBAS systems; therefore, the following scenario describing a flight between Los Angeles and London will assume that all SBASs will use data collected from different RMSs. In the flight the user travels through five different areas of SBAS coverages, as identified below. In this example, the coverage areas will be provided with SIS from the three different SBAS that are currently under development: WAAS; MSAS; and EGNOS.

Area I - Only WAAS signals are received
Area II - MSAS and WAAS signals received
Area III - MSAS, WAAS, EGNOS received
Area IV - MSAS and EGNOS signals received
Area V - Only EGNOS signals are received
Area VI - EGNOS and WAAS received

In **Area I**, the only augmentation the aircraft will receive will be from the WAAS, and it will apply the corrections as it leaves Los Angeles. Near the front edge of Area II, the aircraft will begin to receive the signals from the MSAS.

When the aircraft is well within **Area II**, it will start to use both MSAS- and WAAS-generated signals.

WAAS was the primary SBAS in Area I, and based on the SIS Priority Rules, WAAS may be used as the primary SBAS in Area II until the user reaches the Japanese FIR. Therefore, the GPS correction data will be provided by the WAAS, but both the INMARSAT Pacific Ocean Region (POR) satellite and the MTSAT signals can be used as additional satellites for position determination. Corrections data for the geostationary satellites, such as the MTSAT or INMARSAT POR, will only be provided by the geostationary satellite itself. During the transition to the Japanese FIR, the aircraft's receiver may have to use the MSAS as the primary system, and continue to use the WAAS POR as another ranging source. The user avionics will make the transition evenly, smoothing the difference in the corrections or other messages between the two systems. The use of both geostationary satellites in Area II will improve the availability of SBAS signals, the continuity of navigation, and the overall accuracy due to improvements in geometry.

For some operations, it may provide enough continuity of navigation for sole-means usage. If the user is near Alaska and the ionospheric grid information is available, then it will be used. Also, in the future, if RMSs of two SBASs are connected to the master stations in both SBASs, then the transition will be smoother, since there will be some identical data. Finally, GPS satellites that are only seen by a WAAS user and the MSAS will now be useful, since WAAS, at a minimum, can broadcast the integrity of those satellites.

When the aircraft is in **Area III**, it will be able to receive all three SBAS signals, WAAS, MSAS, and EGNOS. The SBAS selected as the primary system will be based on the SIS Priority Rules. In Area III, it should be the MSAS. The use of all three geostationary satellites will improve availability, continuity of navigation, and accuracy from improvements in geometry. The current RTCA standards require the use of two SBAS satellites for precision approaches. Because of the potential differences in corrections data for GPS satellites from different SBASs, one satellite from each system, e.g., one from WAAS and one from MSAS, users in Area II may not be able to perform precision approaches. Therefore, precision approaches may only be approved when a SBAS has at least two operational geostationary satellites. How the information from each satellite and system will be used in a country's FIR will depend on how the CAA approves and certifies foreign SBASs.

When the aircraft is in **Area IV**, the primary system will change from MSAS to EGNOS. Again, the transition from one primary system to another needs to be smoothed because of the differences in the corrections from each system. Two geostationary satellites are still available to improve performance in Area IV.

Finally, in **Area V**, the user will continue to use EGNOS as the primary SBAS. For a short period of time, only one geostationary satellite, Indian Ocean Region (IOR), is available. Eventually, two satellites, both from EGNOS, will be available. Then three satellites will be available: IOR, AOR-E, and AOR-W.

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FROM GPSNPA TO SCAT-I TO LAAS

ABSTRACT

Having successfully deployed the flight inspection profile for the GPS Non-Precision Approach, Sierra readies its system for LAAS inspections. Using the FAA SCAT-I spec as a model, inspection profiles are being readied for the anticipated LAAS approaches. This paper discusses the design and implementation of an automatic flight inspection system that is used for the inspection of GPS LAAS approaches. Points of interest include database integrity, instrument approach procedure, position determination, VHF data broadcast and interference.

BACKGROUND

The use of Global Navigation Satellite System (GNSS) for terminal navigation is divided into two parts, the non-precision approach (NPA) and the precision approach. The accuracy of GNSS with the Wide Area Augmentation System (WAAS) meets the requirements for en route navigation, non-precision approaches and Cat I approaches for some selected airports [1]. The GNSS with WAAS is not accurate enough to guide aircraft during Cat II and III precision approaches. The GNSS requires a Local Area Augmentation System (LAAS) to increase the accuracy for precision approaches.

The flight inspection of non-precision approaches was originally covered in section 213 (GPS) and later part of section 209 Area Navigation (RNAV) of the United States Standard Flight Inspection Manual (FAA 8200.1a). Currently, the RNAV section of FAA 8200.1a does not cover the precision approach. However, since 1998 there has been a flight inspection evaluation of differential global navigation satellite positioning system (DGNSS) special category I (SCAT-1) instrument approaches using private ground facilities [2].

There are some SCAT-1 systems being deployed around the world. Their future seems to be limited to a small number of facilities, because the equipment required for SCAT-1 is not compatible with LAAS.

SCAT-1 to LAAS

Conceptually both SCAT-1 and LAAS are the same. They are both ground-based augmentation systems (GBAS) that use a differential technique to augment or increase the accuracy of the GNSS. The main difference is the implementation of the data link.

FLIGHT INSPECTION

Database Integrity

If we assume that the LAAS inspection will be similar to SCAT-1 and the GPSNPA, then upon commissioning there will be a requirement to evaluate the procedural design and the database integrity. Figure 1 shows how waypoints for the GPSNPA are entered. Once the first two waypoints are entered, the FIS calculates the distance between the waypoints. It displays the distance and bearing between consecutive waypoints. This is used for the database integrity evaluation. The algorithm would be identical for the LAAS precision approach.

GPS Non Precision Approach

Facility ID :	KEMPE	Threshold Elevation:	250.0
Airport ID :	4B6	Threshold Latitude:	N 43 52 30.0
Runway ID :	20	Threshold Longitude:	W 073 24 28.2
Magnetic Variation:	-15.0	Runway Length:	4000.0
		Runway End Elevation :	250.0
		Runway True Heading :	192.0

ID	TYPE	Latitude	Longitude	Elevation	Range	Bearing
		WAYPOINTS			To Next Waypoint	
KEMPE	IA	N 44 04 34.84	W 073 33 48.76	4000.0	8.8	117.0
SELAK		N 44 02 44.34	W 073 21 54.79	3000.0	5.0	207.0
AQCUN	FA	N 43 57 51.07	W 073 23 22.44	2000.0	4.5	207.0
UGUKY	MA	N 43 53 26.59	W 073 24 41.28	1000.0		

Figure 1. GPSNPA Waypoint Database

Instrument Approach Procedure

The objective of this procedure is to evaluate the flight path for obstacles and ensure safety and flyability. It is not required if a ground-based precision approach exists (ILS or MLS). This procedure and the database integrity evaluations are only necessary at commissioning.

Truth System

The value of an independent truth system for this procedure beyond commissioning is dubious. During commissioning it can help verify that the flight management system (FMS) is operating properly, that the ground station is correctly positioned and differential calculations are getting good data from the data link. But once the waypoints are established, the need to periodically inspect them against an independent truth system has very little value. Unlike other navigation aids that are inspected, an airport maintenance crew cannot adjust the GPS.

Periodic Inspection

During the approach portion of the SCAT I inspection, the flight inspection system (FIS) monitors signals from the GPS as well as the VHF data link (VDL). Table 1 shows the difference between the signals monitored in the GPSNPA and the SCAT I.

Table 1

GPSNPA	**SCAT I**
HDOP	HDOP
	VDOP
HFOM	
Satellites Tracked	Satellites Tracked
S/N Ratio	S/N Ratio
	Date & Time of Day

These parameters are recorded for analysis and have no tolerances associated with them. In the LAAS inspection, the VHF Data Broadcast (VDB -- similar to the VDL in SCAT I) portion of the flight inspection is of the greatest interest. The RF signal strength is inspected in the operational coverage volume. The operational coverage volume is the region in space in which VDB is required to operate. The LAAS approach coverage volume as described in the «LAAS Concept of Operations Draft 4.6» is considerably larger than the one described in the SCAT I procedure. They are summarized Table 2

Table 2

	SCAT I	LAAS
Begin at TCWP	±450 ft	±450 ft
Distance from TCWP	20 nm	20 nm
Lateral Projection from TCWP	±10º	±35º
Vertical	3.0±1.5º	10,000ft to 0.9º AGL at LTP

However, the LAAS approach coverage volume is a small part of the much larger VDB coverage volume. As shown in Figure 2 it is 23 nm with a hole in the center, similar to a VOR coverage volume.

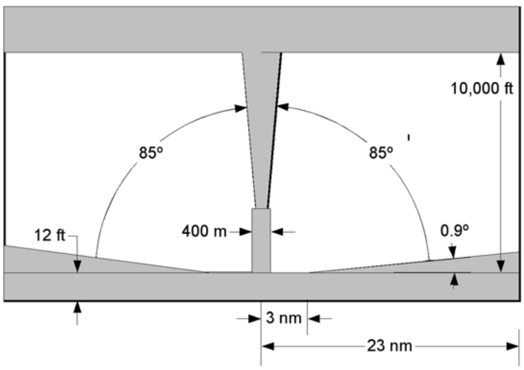

Figure 2 - VDB Coverage Volume

The FIS will monitor the VDB signal strength throughout the coverage volume. From a flight inspection perspective it will be very similar to a VOR orbit inspection. In addition to monitoring signal strength, it will monitor for data link alerts, that is loss of data transmissions.

Much like the GPSNPA inspection, radio frequency interference (RFI) will remain the biggest problem prevailing over the implementation of a GPS landing system. The FAA is currently funding the Volpe Center to develop ground- and air- based equipment that will aid in locating the RFI.

SAMPLE LAAS INSPECTION

Figure 3 shows a sample FIS real-time screen for a LAAS inspection. Across the top of the screen is the type of inspection and the date and time of the inspection. Below that starting on the left is the waypoint ID, type of waypoint (IA-initial approach, FA – final approach, MA-missed approach) followed by the range and bearing to the waypoint. As the FIS approaches the first waypoint it will continually update the range and bearing until it passes though the waypoint. The FIS determines the closest that the aircraft got to the waypoint and freezes the range, bearing and the time of occurrence in UTC. The FIS then advances to the next waypoint in the procedure and continues this process until the last waypoint is passed. Concurrently, on the right side of the screen HDOP and VDOP are being monitored for each segment. A segment is defined as the distance between two waypoints. Along with the current value is the average during the segment. Following that is the worst occurrence of HDOP and VDOP, the time of the occurrence and the range from the beginning of the segment of that occurrence.

Below that is the VDB signal strength, the roll of the aircraft and the number GPS satellites in view. These values can be plotted during the entire profile. Further down is the ID or PRN of each satellite in view and the signal-to-noise ratio of each one.

```
GPS LAAS Approach    KEMPE                                  2000-Jun-09:09:28:15

WP ID Type Rng   Brg    UTC                        Avg     Worst   UTC      Range
-------------------------------------------------------------------------------
KEMPE  IA  0.01  48.7  13:23:50 | HDOP    1.66    1.54    1.7  13:28:35   4.78
SELAK      0.02 162.5  13:28:14 | VDOP    7.4     2.5     9.1  13:28:38   4.66
AQCUN  FA  3.98  27.2  13:28:42 |
UGUKY  MA                       |
                                |
                                | VDB SS -38.5
                                | ROLL      0.5
                                | SATS        6
ID    13    02    16    21    07    12
S/N   35    47    56    36    43    62
-------------------------------------------------------------------------------
     HDG 207.2                        AGL   2480                   RNG    3.98
     GS   122                         MSL   2730                   BRG   27.2
-------------------------------------------------------------------------------
     CDI                              CP
-------------------------------------------------------------------------------

-------------------------------------------------------------------------------
   TAC/DME1    TAC/DME2    NAV    sec NAV  Tkr   MLS                  BUFFERS
     RB          RB        LGV        LGV   *    AE                      2
-------------------------------------------------------------------------------
```

Figure 3. Sample Sierra Real Time FIS Screen

The lower half of the real-time screen includes general information standard for all flight inspections.

QUESTIONS

Are periodic inspections good enough during the first phase of deployment of LAAS? Perhaps there should be temporary ground stations at some facilities that continually monitor signal strength, data link alerts and RFI continuously for a year or more. All-day monitoring could check for interference from radio stations when they switch transmitting power from day to evening levels. Over a period of a year, there is a chance to monitor the effects of weather. Data from these monitors could give an indication if a six- or nine- month period between inspections is sufficient.

CONCLUSIONS

There are few challenges in implementing flight inspection of a LAAS approach. Database integrity, instrument approach procedures and position determination are the same as the GPS non-precision approach. Inspecting the VHF data broadcast for signal strength is quite similar to inspecting for VOR signal strength. The biggest challenge for flight inspection of LAAS will be detection of interference.

REFERENCE

[1]http://gps.faa.gov/Programs/WAAS/waas.htm

[2] FAA 8200.41 Flight Inspection Evaluation of Differential Global Navigation Satellite Positioning System (DGNSS) Special Category I (SCAT -1) Instrument Approaches Using Private Ground Facilities

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AIRFIELD INITIATIVE

ABSTRACT

This paper provides a description behind the collection of a comprehensive set of geospatial information around airfields to support Global Navigation Satellite System (GNSS) instrument approach procedures. The major themes of the paper revolve around the features and applications of the program. In specific, the presentation describes the data sets, which are based on a single geodetic (WGS-84) system. This concept allows for all of the data, which is collected, to be controlled to one base layer of information. The data conforms to the International Civil Aviation Organization (ICAO) standards and as a result of this methodology; airfield feature and obstruction data will be consistent with each other. An Airfield Elevation Model (AEM) with 30 meter spacing encompassing a 14-kilometer radius is created for each airfield.

In addition to the direct application of using this data for designing approach procedures, pilots will be able to use this information for flight training, pre-flight flythrough familiarizations, as well as increasing overall aircrew situational awareness relating to mission planning. The ultimate goal of the Airfield Initiative Program is to aid in the safe transition to the GNSS environment supporting a safer flying environment.

BACKGROUND

The National Imagery and Mapping Agency (NIMA) is collecting a comprehensive set of geospatial information around airfields specified by it's customers. The geospatial information will be collected using a combination of sources, to include imagery, surveys, and Host Country information. NIMA is collaborating with the Federal Aviation Administration (FAA), industry, other government agencies, and international communities to develop a global integrated Safety of Navigation information environment.

There are two issues that challenge air safety today. We have airframes with diverse levels of technology and we have more airplanes competing for airspace. Today's aircraft use various ground-based navigational aids to traverse to the airfield area and onto the runway. Some of these navigational aids have remained virtually unchanged since the 1930s. Our challenge is to address all factors concerning air safety.

Knowing the location of the aircraft is, however, only half of the solution. To bring an aircraft safely onto the runway with little else than satellite navigation, the pilot will need very accurate and reliable geodetic coordinates for the runway. Currently, published airport and runway end coordinates are intended only to get the pilot into the general area. Pilots are expected to use conventional navigation aids or visual contact to direct the aircraft to the runway. The aeronautical community recognizes this acute need for accurate geospatial information in and around the airfield, specifically for accurate runway positions, obstruction locations and heights, and topography around airfields. Collecting this information is the initial step for the Airfield Initiative Program.

Realizing that interoperability is critical to flight safety, the International Civil Aviation Organization (ICAO) made the first step by recommending the World Geodetic Survey 1984 (WGS-84) be used as the standard datum for all international flight operations. A common datum ensures that pilots, controllers, and other support activities are all talking about the same place. The ICAO goal is to provide safer air transportation by using a consistent and universally recognized, accurate geodetic reference frame for air travelers.

The United States (U.S.) must keep pace and maintain compatibility with civil improvements and technology advancements, or their aircraft will not be capable to execute precision approach and landings. To this end, NIMA, in conjunction with FAA, and Host Countries, is orchestrating the collection, exploitation, and dissemination of airfield information. This effort will provide a common reference frame for air operations and information critical to flight safety.

Technology is now addressing this need for accurate information. The Global Navigation Satellite System (GNSS) is making changes to the way the world navigates. Full exploitation of a GNSS will provide a seamless, all-weather, interoperable, cost effective solution to many of the air traffic needs. This will not only improve safety, but will free pilots from confinement to specific air lanes serviced by ground-based navigation aids. With Global Positioning System (GPS) receivers in automobiles, aircraft, and ships, this intricate system of satellites is moving us to a new era of travel. Rather than rely on a network of ground-based navigational aids providing direction point-to-point, pilots can access continuous feedback on their flight plan in three dimensions. Exploitation of GNSS/GPS can greatly enhance safety to air travel. However, even with technology advances, all countries will not have that technology. Technology can only mitigate the risk; it cannot solve the crowded skies dilemma.

«Controlled Flight Into Terrain» continues to be a major source of aircraft loss in the aviation community. To reduce the incidence of those accidents, the Airfield Initiative Program is providing the necessary information that will support a suite of displays that integrate imagery, terrain, obstacles, and features. With this information, aircrews can gain the advantage of situational awareness, regardless of external visibility conditions.

AIRFIELD ELEVATION MODEL

Definition/Description

The Airfield Elevation Model (AEM) created by the Airfield Initiative will encompass an area extending 14KM from each runway end joined by the tangents from the other runway(s) end.

The AEM consists of a one arc second post spacing model. By using the reflective surface the

1) Terrain data will be extracted on the reflective surface (the data shall reside on the top of the vegetative surface - tree tops or manmade surface - roof tops, etc.). If a terrain post falls on top of a feature, the surrounding terrain posts shall portray the reflective surface, which may include the dirt surface. Interpolation between posts located at the tops of features is not acceptable if the interpolated post does not portray the true reflective surface.

2) When extracting digital terrain over patchy tree areas, the terrain data will be edited such that all of the elevation posts reside at the tops of the trees while conforming, in parallel, to the surface of the terrain.

3) Elevations in ocean areas, that have photo coverage, will be populated with the value of 0m. Elevations in inland water areas, that have photo coverage, will be populated with their

actual elevation value in meters. Elevations in areas that have no photo coverage shall be populated with the value of -32767m (Digital Terrain Elevation Data null).

4) Terrain will be stored in complete 1-degree AEM cells. Where there is no photo coverage to determine elevation values for the AEM cell, elevation points will be populated with a null value (-32767m). For more detailed information see the NIMA web site for Digital Terrain Elevation Data (DTED(), Performance Specification dated, 19 April 1996 at http://164.214.2.59/publications/specs/printed/DTED/DTED_1-2.html.

5) The following fields in the header for the AEM cell shall be filled as described below:

- Unique Reference Number: ICAO Designator number, which is found in the Expanded Airfield Facility Report.

- Data Edition and Match/Merge versions: Dependent on Edition and Match/Merge versions. First releases should have '01' and 'A'.

- Producer Code: 'US NIMA'

- Actual number of latitude and longitude lines. Literal count of the Latitude and Longitude lines. Example, if the cell falls within the 50-degree latitude boundary then the count should be 3601 latitude and 3601 longitude.

Data Requirements

To support the Airfield Initiative both photogrammetric and survey data is required.

Photogrammetric and Survey Data Requirements

The following are required:

Primary and Secondary Airport Control Stations (PACS & SACS) are established in the vicinity of, and usually on, an airport, and are tied directly to WGS-84. They must meet specific requirements for siting, construction, and accuracy. Because of these requirements, they can only be delivered by placing survey teams on the ground. Since a number of the specified airfields are not accessible to U.S. survey teams, delivery of PACS and SACS depends on NIMA's ability to contract or acquire this information from other producers (via agreement or purchase).

Airfield feature data, such as runway end coordinates, must be surveyed in order to achieve the required accuracy. This information will be supplemented with photogrammetrically derived data for those features having a less stringent accuracy requirement.

Vertical obstruction information can be collected using a combination of photogrammetric and survey techniques.

The Airfield Elevation Model collection will utilize National and commercial imagery. Commercial imagery will be evaluated for airfield work when the imagery becomes available. National Aeronautics & Space Administration (NASA) and NIMA, co-sponsors of the recent Shuttle Radar Topography Mission (SRTM), anticipate the benefits of the SRTM data to improve air safety. Once the SRTM global data is available the 30-meter density of elevation points for airfields will be available. [The 30-meter data over the continental U.S. will be publicly releasable, whereas, the 30-meter data outside the continental U.S. will not be publicly releasable.]

OBSTRUCTIONS

An obstruction is any object that penetrates an obstruction identification surface (OIS) as defined below, except where no obstruction penetrates the OIS; then the obstruction is the highest object within the area. The OIS consists of several surfaces related to a specific runway. (An airfield containing multiple runways will have multiple OIS.)

Primary Surface and Clear Zone

The Primary Surface is an imaginary surface, longitudinally centered on each runway, equal to the length of the runway plus 1000 feet on each end, and a width of 2000 feet.

- For the purposes of determining obstacles on the sides of the runway, the Primary Surface is referenced horizontally to the runway ends and vertically to the lowest runway end elevation.

- For the purposes of determining obstacles in the approach/departure zones, the horizontal and vertical reference point is the runway end.

Approach Surface

The Approach Surface is an inclined plane, symmetrical about the runway centerline, beginning 200 feet outboard of the runway end point, at the height of the runway end point and extending for 42,332 feet (7nm - 200 feet of primary surface). The slope of the approach clearance surface is 50 to 1 along the runway centerline extended until it reaches a height of 500 feet above the height of the lowest runway end elevation. It then continues horizontally at this height to a point 42,532 feet (7nm) from the end of the runway. The width of this surface at the runway end is the same as the primary surface, it flares uniformly, and the width at 42,532 feet is 13,899 feet.

- The vertical reference point for the 50:1 slope surface is the height of the runway end.

- The vertical reference point for the horizontal approach/departure surface is the height of the lowest runway end elevation.

Primary/Approach Transitional Surface

The Primary/Approach Transitional Surface connects the side of the runway primary and approach surfaces to the inner horizontal surface.

- The surface extends outward, perpendicular to the centerline of each runway, from the edges of the primary surface, at a slope of 7:1 to a width of 1,050 feet and a height of 150 feet above the lowest runway end elevation.

- The surface extends outward, perpendicular to the extended runway centerline from the edge of the approach surface at a slope of 7:1 to a height of 150 feet above the lowest runway end elevation.

Inner Horizontal Surface

The Inner Horizontal Surface for each runway is defined by two half circles centered on the runway ends and joined by tangents. The radii of the half circles are 7,500 feet and the tangents are parallel to the runway centerline at a distance of 7,500 feet. The surface is a constant 150 feet above the lowest runway end elevation on the airport.

Conical Surface

The Conical Surface is a surface extending from the periphery of the inner horizontal surface outward and upward at a slope of 20:1 for a horizontal distance of 7,000 feet to a height of 500 feet above the lowest runway end elevation on the airport.

Outer Horizontal Surface

The Outer Horizontal Surface is a plane located 500 feet above the lowest runway end elevation on the airport, extending outward from the outer periphery of the conical surface for a horizontal distance of 28,031 feet.

Conical/Outer Horizontal Approach Transitional Surface

The Conical/Outer Horizontal Approach Transitional Surface connects the side of the Approach Surface to the Conical and Outer Horizontal Surface. The surface extends outward, perpendicular to the extended runway centerline from the edges of the approach surface, at a 7:1 slope. The slope of the

7:1 surface is referenced to the runway centerline. (See Figure 1 for an OIS Visualization Aid and Figure 2 for a sample aerodrome showing AEM, OIS, Airfield Features and Vertical Obstructions.)

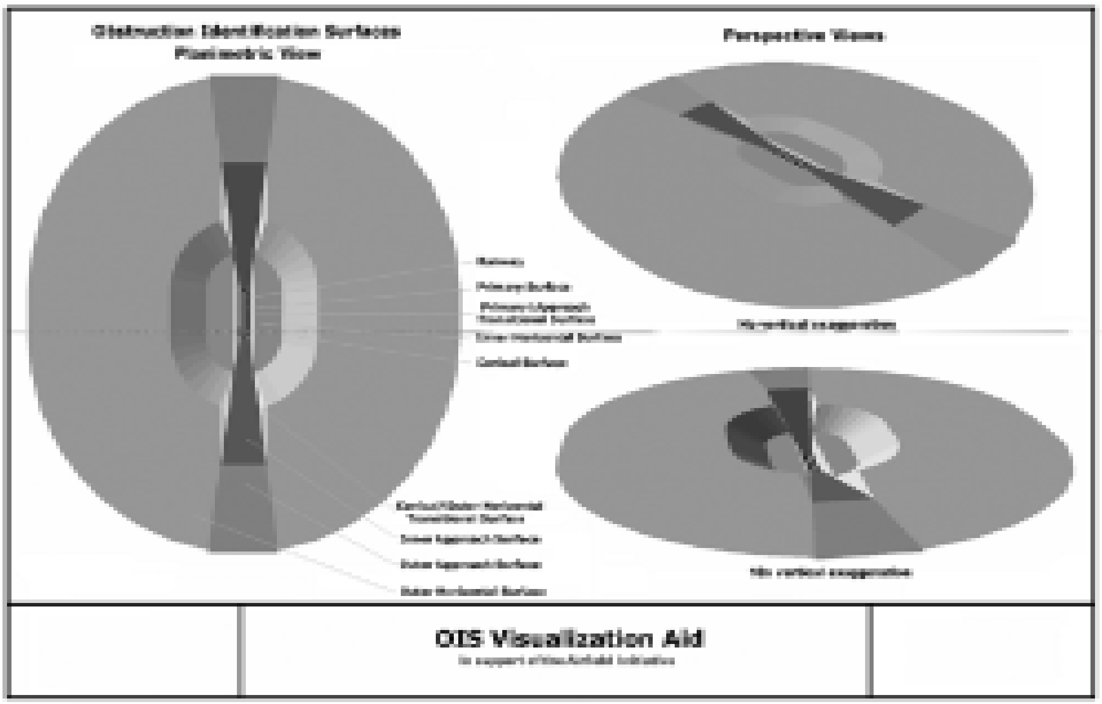

Figure 1 - OIS Visualization Aid

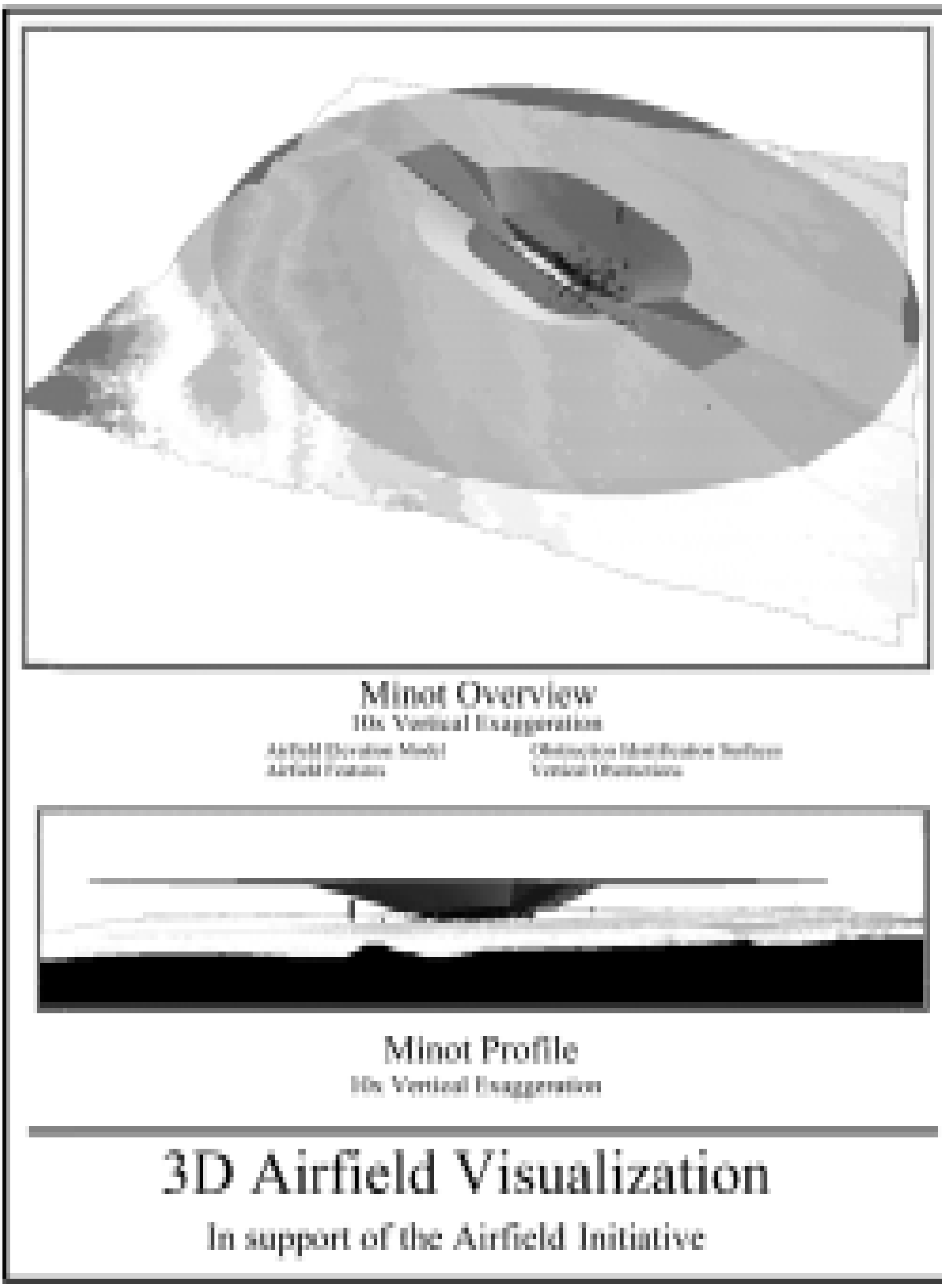

Figure 2 - Sample aerodrome

CONCLUSIONS

NIMA has established partnerships with a variety of organizations and individual countries in order to obtain currently available data, and is seeking participation from countries worldwide to enhance aviation safety through this program. The data assembled through this project will be used in the future to enhance flight safety even further. Some of the possibilities include 3D perspective scene generation; whereby a pilot could «see» the approach from the airplane's perspective. This would be especially helpful when a pilot has never flown to a particular airfield, allowing him or her to become familiar with the terrain and obstructions before leaving the ground. The pilots will be able to practice landings using inexpensive flight simulation software.

The NIMA Airfield Initiative Office plans to host an Internet web site that will be available later this year. The web site will contain information about the Program and will track the progress of the Program throughout its life.

REFERENCES

1. FAA 405: Standards for Aeronautical Surveys & Related Products

2. FAR 77: Obstructions Standards

3. FAA Handbook 8206.3: US Standard for Terminal Instrument Procedures

4. RTCA DO-201A: Standards for Aeronautical Information

5. RTCA DO-200A: Standards for Processing Aeronautical Information

6. ICAO Document, World Geodetic System-1984 Manual

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FAA's NEW CENTRALIZED FLIGHT MONITORING AND SCHEDULING SYSTEM

ABSTRACT

The Federal Aviation Administration (FAA) has recently implemented a new system called Centralized Flight Monitoring and Scheduling System (CFMSS) to increase the efficiency in the management of crew and aircraft resources which perform facility inspections in the United States (US) and around the world. This system automates several functions which have previously been performed manually. As a result, a reduction of total flight hours has been achieved in the FAA flight inspection mission.

The CFMSS System consists of several major components which are all integrated to provide seamless operation to schedule and to control flights in real-time in accordance with Federal Aviation Regulations (FAR), Part 135. The scheduling component encompasses the preparation of flight itineraries based on the facility inspection requirements, and the selection of qualified crew and available aircraft to complete the mission. The real-time control of flights consists of dispatching and flight monitoring/flight following. CFMSS makes extensive use of the data link system to report to the central ground operations real-time aircraft locations and status of the facility inspections.

The CFMSS System is driven by a large Oracle database and many functions accessible via the Internet. This approach permits all users of the system (schedulers, dispatchers, crew, facility maintenance personnel) who have proper authorization access to obtain from anywhere in the world any desired information which is stored in the database.

INTRODUCTION

The FAA's Office of Aviation System Standards (AVN), located in Oklahoma City, Oklahoma, USA recently undertook a major effort in automating and centralizing the operation of their entire fleet of some 30 aircraft. Previously the operation was controlled from five Flight Inspection Field Offices (FIFO) located throughout the continental US. Each of the five FIFO's provided its own personnel to schedule the inspection of the facilities located within the area of the FIFO, and assign crew and aircraft to perform the mission. This method of operation required a staff at each of the FIFO's to schedule the inspection of facilities and assign the aircraft and crew resources available at the FIFO. The inspection of facilities by the crew was not performed in an efficient manner because the crew made up their own itineraries from the list of facilities given to them at the beginning of the mission. In addition, each FIFO was strictly responsible for the facilities within its own border, and seldom achieved the benefit of sharing aircraft resources from a neighboring FIFO for those facilities located near the border.

AVN proceeded to establish a system that was compliant with FAR Part 135 regulations. In effect the FAA Flight Inspection fleet would operate under the same rules as a small commercial airline company. In 1994 AVN contracted Parker Hannifin - ESD to develop a system that would centralize the scheduling, dispatching, and flight following operation in Oklahoma City. The role of the FIFO's were modified to act as a resource pool for aircraft and crews, but the day-to-day control and direction for each of the missions would then be established centrally in the Flight Inspection Central Operations Office (FICO) in Oklahoma City.

FUNCTIONAL OVERVIEW OF CFMSS

The various components of CFMSS are tightly coupled and integrated to function as a seamless system. It is more effective to describe the relationship of each component in a flow diagram, which is depicted in Figure 1. After describing the top-level functionality, the details of each of the components will be discussed.

CFMSS automates the process of Flight Inspection scheduling, dispatching, and Flight Following in a single integrated system. It encompasses operations to schedule facility inspections listed in an Itinerary, dispatch a flight, follow the status of each flight, and update arrival information at the completion of a flight. Tools are provided to display available aircraft and crew, view Itinerary, airport and aircraft information and complete a Daily Flight Log (DFL) at the end of a duty day.

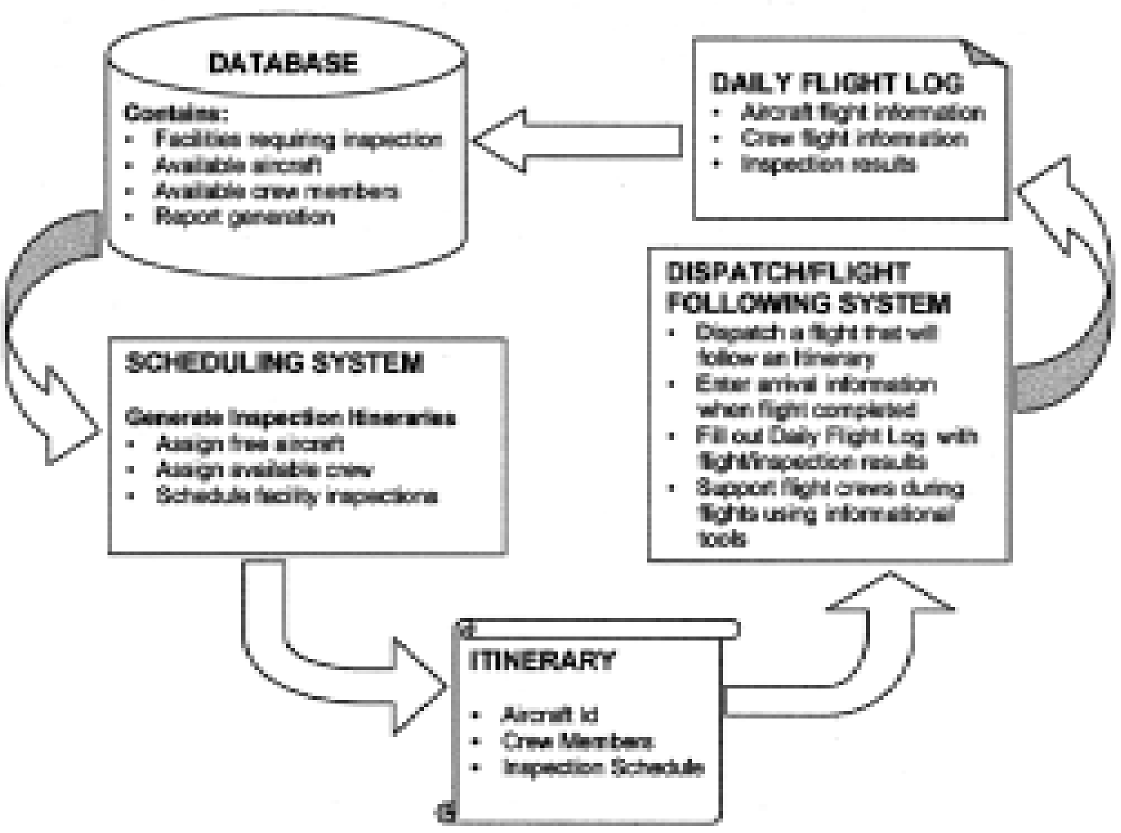


Figure 1. Flight Inspection Work Flow

Database

The Database contains three major components: (1) parameters for each facility and its next inspection due date, (2) list of available aircraft for flight inspection and maintenance status of each aircraft, and (3) crew members with medical, training and leave status. Mandatory crew rest periods are also considered when scheduling flight inspection missions. The Database content can be used to generate various reports as needed by FAA personnel. The reports provide information on facility inspection history, crew flight times, aircraft utilization, and inspection productivity.

Schedule Inspections

The first step in the Flight Inspection workflow is the scheduling of inspections for facilities with inspections due. Using the Scheduling system Map program, the user creates a new Itinerary and chooses facilities on the map to be added to the Itinerary. Once the facilities have been added, the user can choose an aircraft from the available list, and then assign available crew members. At the completion of the scheduling step an Itinerary is ready to be dispatched.

Create an Itinerary

An Itinerary is created for each aircraft before it is dispatched on a flight inspection mission. The Itinerary contains the crew members assigned to a flight, and the routes which the scheduler has planned for one week's mission. All facility tasks and their related information, such as facility ident, facility type, type of inspection due, open/due/close window dates, and special control numbers are held in the Itinerary. The Itinerary allows the scheduler to monitor the planning activity in alphanumeric format.

Dispatch a Flight

Using the Dispatch system the dispatcher chooses an Itinerary and creates a dispatch release for a flight. The Dispatch system automatically fills in the aircraft and crew information from the Itinerary into the dispatch release, as well as weather and Notices to Airmen (NOTAM's) for the route of flight. The dispatcher adds Estimated Time of Departure (ETD) and Estimated Time of Arrival (ETA) information and submits the release to the system for final verification. The Dispatch system will verify the information in the dispatch release, including required qualifications and rest periods for the crew members. When verification is complete the system adds the flight to the flight following list as an active flight. The dispatcher can print out copies of the Itinerary and dispatch and include them in the documentation that the crew carries during the flight.

Update Arrival Status of a Flight

When a crew finishes a flight leg and lands at an airport the dispatcher is notified with the actual times of departure and arrival along with the status of the flight. The dispatcher uses the Dispatch system to update the departure time and adds the arrival time and location information. The system closes out the flight and the flight following list is updated to reflect the arrival status. The aircraft and crew flight time data in the CFMSS system database is automatically updated to reflect the newly added information. If additional flight legs are required for the Itinerary, the dispatcher repeats the Dispatch and Arrival steps. At each step the CFMSS database is updated and the dispatch verification is performed on the most current information.

Complete Daily Flight Logs

Once the crew has completed all flights for the current duty day, the dispatcher can create a Daily Flight Log (DFL) report. The DFL contains summary information on the aircraft and crew flight times and the inspections completed during the day's flights. Most of the information in the DFL is automatically generated using the flight data gathered from the Dispatch system. Once the DFL is completed and checked by the appropriate personnel it is submitted to the CFMSS system. The inspection results in the DFL are used to update the CFMSS database and the next inspection date for each facility is computed. When these inspection dates arrive, the facilities will appear again on the Scheduling system Map and the cycle will repeat.

CFMSS FUNCTIONAL DESCRIPTION

Operation of the CFMSS is accomplished with a locally-based XWINDOWS$_{TM}$ operating system used in conjunction with a Web-based operating system. Both the XWINDOWS$_{TM}$ and Web operating systems function in a WINDOWS$_{TM}$ type environment, which utilizes a series of display elements that are selected by an operator controlled cursor. The XWINDOWS$_{TM}$ operating system encompasses the scheduling function while the Web-based operating system encompasses the aircraft dispatch and flight following functions. The modules interface real-time with the Oracle database which contains the facility/ flight scheduling data, as well as the crew and aircraft information.

An overall functional diagram of the CFMSS interface is illustrated in Figure 2. The system consists of user terminals that interface with the internet for access to active Web-based programs and the CFMSS database. The user terminals are configured with a WINDOWS$_{TM}$ operating system and include a browser for access to the Web and an XWINDOWS$_{TM}$ module for access to the XWINDOWS$_{TM}$ active programs.

SCHEDULING

Flight scheduling encompasses the generation and modification of flight itineraries, including assignment and scheduling of facility tasks and the processing of Itinerary reports. All Itinerary generation, viewing and modifications are performed from the CFMSS-Central Scheduling platform. When the scheduler opens up the Scheduling Program a map of the entire United States appears, showing all facilities that are due for inspection. The Map area is the main platform used for Itinerary operations. Areas selected can be displayed with an overall view or can be zoomed in to display a few miles per scale inch. Zoom-in/out is available as a progressive or area-selectable operation. In full zoom view the state boundaries and routes of any open itineraries are displayed, and the symbols representing facilities requiring inspection begin to appear.

A typical map which is zoomed in to the state of Oklahoma is illustrated in Figure 3. The key attributes of the map display are state boundaries, facilities requiring inspection, and a bar-chart to indicate time-line status of each facility's inspection timetable.

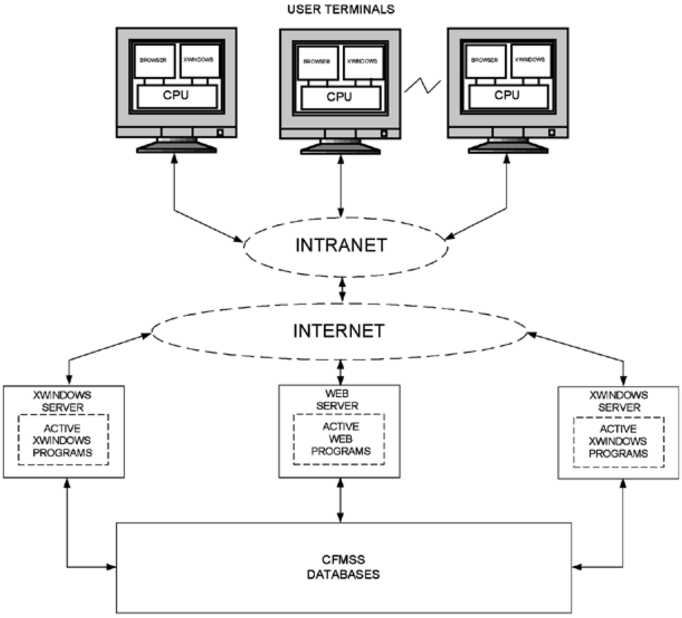


Figure 2. CFMSS Architecture and Interfaces

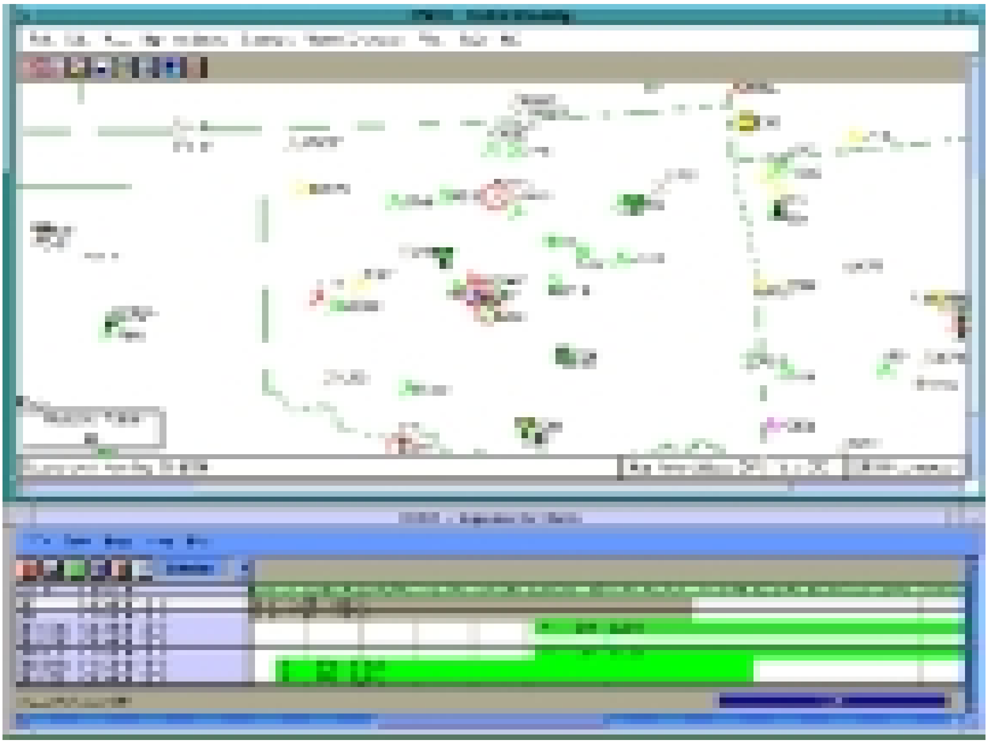


Figure 3. Flight Scheduling Map and Bar-chart Time Line

Facility Symbol Indication

Each facility that is due for inspection is represented in color on the Map by a Jeppson-type symbol, with the following exceptions:

a) An Airport (crossed runways) symbol is used to represent all facilities which have been identified in the database as being contained within that airport. Typical facilities contained within the Airport symbol include ILS, MLS, GPS, and PAR, including their sub-components. Radar, Procedures, NDBs, Communications, VORTAC and other facilities can potentially be denoted as related to a specific airport, in which case they will be represented by the airport symbol.

b) Procedures which are not related to an airport or when a Map is printed are represented by a diamond symbol.

c) Radars (ASR, SECRA, etc.) have similar but distinctive radar-dish/mount symbols.

Facility Symbol Color and Position

Each facility symbol displayed on the Map is represented by one of four colors, used to indicate the relative urgency of the inspection task requirement related to that facility. The most urgent task requirement for that facility is used to determine the color used. Additionally, a facility which has been marked in the database with the Special Category as «Special» is reflected on the Map in the same manner as the facility symbol, i.e., colored in accordance with the same urgency code, but with a Red Circle around it. The following describes the color-coding of facility symbols on the Map:

GREEN	More than 2 weeks to Close Window
YELLOW	Within 3 weeks of Open Window
MAGENTA	Within 2 weeks of Close Window

RED Overdue
RED Circle SPECIAL

The relative placement of facility symbols on the Map is determined by the Latitude and Longitude entered into the facility database.

Bar-chart Window

The Bar Chart is used in conjunction with the Flight Scheduling Map to indicate, with increased resolution, the relative time-line inspection requirements for all facility tasks stored in the database. The Map and Bar Chart are linked for operating convenience. When the Map program is loaded and an airport or single facility on the Map is selected, the facility designated is automatically reflected on the Bar Chart display.

Tasks listed on the Bar Chart are sorted alphabetically by state and then by location and airport ID. Each task is identified by a facility Ident, facility type, state, location, and airport (if applicable).

The bar section of the chart contains a colored bar corresponding to each task (for the queried criteria) that is held in the database. If the database holds no tasking data for a facility, it will not appear on the list. Type of check is provided on each bar (i.e., Periodic, Periodic with Monitors, Annual, Special, etc.) as well as the control number for Specials. A vertical timeline marks the current day, while the month, day and year are listed along the top line of the Bar Chart display.

Creating an Itinerary

The Itinerary Schedule is the display which contains the routes which the scheduler plans for a week's mission. All facility tasks and their related information, such as facility ident, facility type, type of inspection due, open/due/close window dates, and special control numbers are held in the Itinerary. The Itinerary allows the scheduler to monitor the planning activity in alphanumeric form, while the Map indicates the planned route in graphical form. All scheduling activities are performed from the Map.

Once an Itinerary Schedule has been opened or created, the program assumes this as the start base for drawing the route legs, i.e., the first leg will originate from the designated FIFO. There are several ways that a facility task can be scheduled, but in each case the mouse pointer and left mouse button are used to click on the facility symbol. This action includes the selected facility into the Itinerary. As the Itinerary is developed, the flight legs between the selected facilities are connected to indicate the flight path of the aircraft performing the inspection. The sequential list of facilities to be inspected are displayed in the Itinerary schedule which is illustrated in Figure 4.

Once an Itinerary Schedule has been generated and the route completed, a section of the Map displaying the intended route can be printed to accompany the Itinerary Report. Once printed, only the facility symbols corresponding to the scheduled tasks will be drawn, along with the route legs and associated Ident. The Itinerary Report and associated map is then sent to the FIFO from which the flight inspection mission will originate.

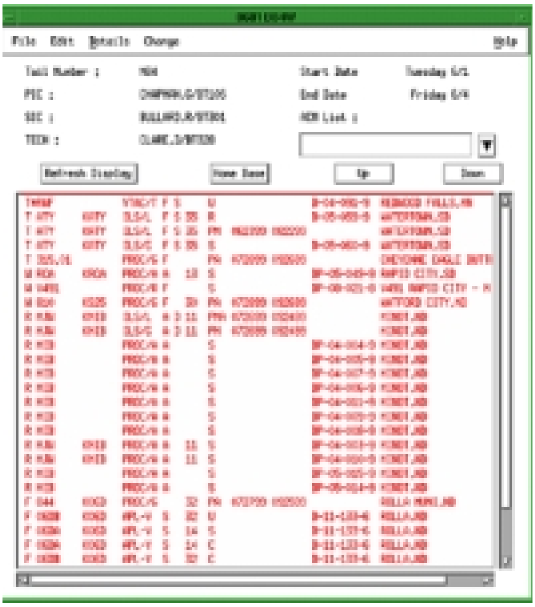


Figure 4. Itinerary Report

DISPATCH/FLIGHT FOLLOWING

The Dispatch and Flight Following system functionality has been developed to fully comply with FAA FAR, Part 135.

Dispatch System Functional Summary

The primary purpose of the dispatch system is to provide qualified crew and airworthy aircraft to complete the flight mission as specified in the Itinerary Report. The crew members are validated based on current medical status, training, skills, stand-by status, and the crew member's ability to complete a weekly, or two-week duty block without conflict. These soft constraints are applied during coordination and scheduling of each Itinerary. Real-time compliance warnings to the operator include items such as crew rest period, qualification criteria, and aircraft maintenance warnings. Options are provided for making aircraft swaps and crew changes before and during a flight inspection mission. Likewise, the aircraft's configuration for the type of flight inspection mission is validated for the planned Itinerary.

This system provides a user interface to the functions that capture and record pre-dispatch data through a process of the following:

- Compute the aircraft's weight and balance systems using EXCEL spreadsheets.
- Obtain and record current weather information for user defined airports automatically.
- Obtain and record current NOTAM's for user defined airports automatically.
- Obtain and record facility special clearance requirements automatically, if applicable.
- Obtain and record airport information as applicable.
- Print and FAX dispatch briefing to Fixed Base Operator (FBO), or send dispatch briefing to the aircraft through the Datalink system.
- Record Pilot in Command's agreement, or comments regarding mission brief.
- File and Record Flight Plan (not yet implemented).
- Record and print the accepted dispatch release.

Flight Following System Functional Summary

The Flight Following and Monitoring system provides for real-time recording of aircraft movements by collecting the aircraft's Out, Off, On, and In, ETA, and planned next off times automatically with manual entry capability. The system interfaces directly with the DFL and records events required by the DFL. The international dates and time lines are recorded and managed to track the movements of continental and international flight inspection missions. Changes in the mission plan are captured and recorded via predefined codes for dispatch deviation occurrences. A planned crew duty day is recorded, and any deviation changes to the time line are captured via predefined codes. Alarms are automatically generated for overdue aircraft.

Dispatch/Flight Following User Interface

This paragraph provides an overview description of the Web-based Flight Inspection Dispatch and Flight Following operation. Figure 5 represents the screen which consists of four main sections:

- Internet Explorer Browser Area
- Dispatch Menu Bar
- Flight Following Display
- Dispatch General Work Area

The Internet Explorer Browser Area consists of the standard menu and toolbar displayed by the Microsoft Internet Explorer web browser. The Dispatch Menu Bar is used to select the desired Dispatch function. When the cursor is placed over the desired menu header it becomes highlighted.

Home Header - provides a means for refreshing the Web page and returning to the original format.

Resources Menu - provides the means for determining aircraft and crew member availability for flight inspection missions.

Operations Menu - provides access to the flight inspection mission operations functions and information related to the flight inspection mission as described below:

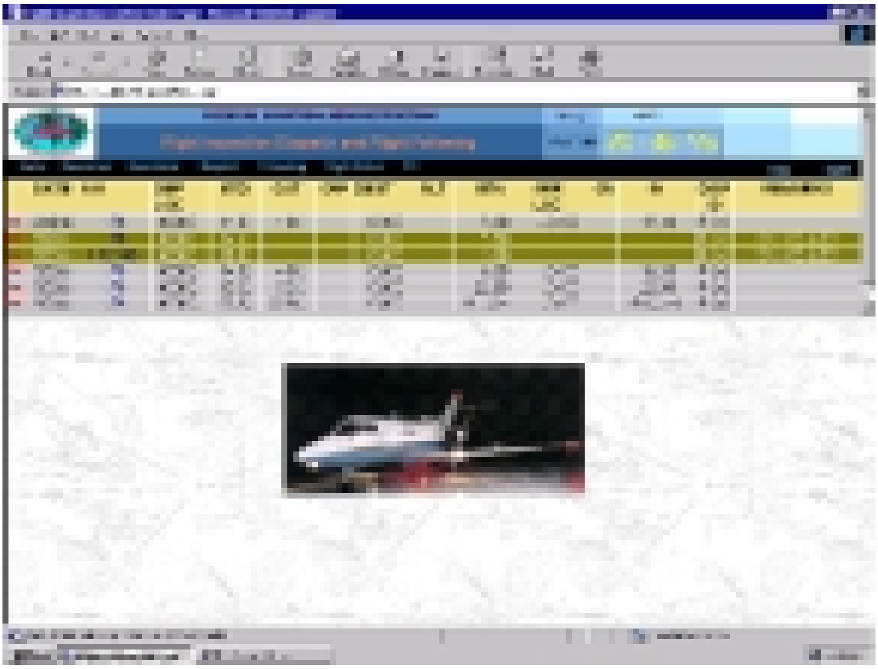


Figure 5. Dispatch/Flight Following Main Screen

- **Authorization** function allows a user to create a new flight authorization and to view or edit an existing flight authorization.
- **View Itinerary** function allows the user display and view all itineraries that have been created in the system.
- **Fleet Status** function displays a list of the current maintenance status of the selected aircraft.
- **Passdown Events** is a feature to allow the sharing of scheduled events and passing of important information between the users of the system working differing shifts and in different locations. Passdown events can be accessed for viewing events, editing events (rescheduling), and scheduling new events.
- **Overnight Information** function allows a user to add, view or edit overnight hotel and FBO information for a crew.
- **Airport Information** screen displays comprehensive airport information.
- **FBO** screen provides the means for retrieving the name and phone number of the Fixed Base Operators at the specified airport.
- **Hotel Information** function allows a user to search for a hotel based on a location and a number of accommodation preferences.
- **Domestic and Foreign Per Diem Information** provides access to the FAA Per Diem web sites.

Dispatch Menu - provides the means for dispatching a flight segment from an Itinerary, special authorization, or by manual entry. The Dispatch menu also provides access to various weather briefing services and to spreadsheets that calculate weight and balance parameters for various FAA aircraft. In addition, the user can access information for calculating, viewing, and filing flight plans. The functions are described below:

- **New Release** - menu item allows a dispatcher to release a flight. This screen provides three sources of flight information to choose from for the dispatch. The source choices are:
  a) Release from a scheduled Itinerary
  b) Release from an authorization
  c) Generate a manual release

- **Weather** - menu items provide links to three different weather service providers as follows:
  a) UNIVERSAL
  b) WSI
  c) DUATS
- **Weight and Balance** - function provides access to spreadsheets that calculate weight and balance parameters for various FAA aircraft.

Following Menu - is the primary place the dispatcher will keep track of the active flights. Filter, Sort, and View menu items are provided to allow the operator to display the flight segments in a desired arrangement. The flight segment turns yellow when it becomes overdue for 60 minutes, then it turns red to show one hour overdue flight. Functions are provided to filter the database to display flight segments for a selected FIFO and aircraft tail number, sort the order of flight segments, and view only those flight segments which fall within a selected time span. Operation of these functions are briefly summarized below:

- **Filter** - menu item provides a method of limiting the flight following list to a subset of the flights that have been dispatched. The filtering options are:
  a) Filter by FIFO location
  b) Filter by Tail Number
- **Sort** - menu sets the order in which the flight segments are displayed in the Flight Following list. The list may be sorted by the following parameters:
  a) Tail Number
  b) Estimated Arrival Time
  c) Estimated Departure Time
- **View** - menu sets the parameters that limit the date range for which the flight segments are displayed in the Flight Following list. The date range can be specified by the following parameters:
  a) Today
  b) Current Week
  c) Last Two Weeks
  d) Date Range (From and To date)

Flight Status Menu - displays the current day and previous day flight segments. The flight status list can be limited to a subset of the flights that have been dispatched using filtering by either FIFO location or aircraft tail number. For each aircraft tail number there is a «crew duty day» bar which represents the duty day. This bar can be adjusted as required on each segment. When overtime is approved this bar is extended.

Delay and event codes can be viewed and edited on this screen. When the delay/event codes are entered, the active flight bar is adjusted to the correct size and color to display the delay. The user chooses a delay code and assigns the times of the delay. This information is stored for reporting purposes.

DFL Menu - provides the means for viewing, editing, and creating DFLs (Daily Flight Logs). In addition system reports, which describe a variety of Flight Inspection mission details, such as aircraft, crew, and fleet activity, facility history, DFL audit trail, division productivity, and others can be accessed from the DFL menu.

The DFL form is used to track aircraft utilization, crew utilization and work accomplished during inspection flights. Each DFL form contains information for a specific aircraft, as flown under a specific Pilot in Command (PIC), during one duty day. The DFL form subsystem is tightly integrated with the CFMSS Scheduling and Flight Inspection Dispatch programs and under normal conditions much of the data in the form will be filled in automatically.

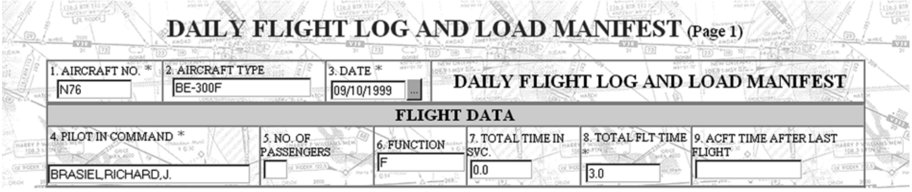
When a flight is released using the Flight Inspection Dispatch system a DFL is created. Each time that the departure and arrival information for a flight is updated, the information regarding each flight leg will be automatically added to the DFL. Flexibility is provided for the operator to:

a) Create a new DFL and manually enter all data
b) Retrieve an existing DFL
c) Retrieve an outstanding DFL
d) Retrieve a specific DFL associated with a flight leg

DFL User Interface

The DFL is a FAA Form 4040-5, which includes several sections, whose content is described below. If the DFL is created manually, then all fields will be blank and all data will need to be entered by the operator. If the DFL already exists, many of the fields will already be filled with data generated during the dispatch process or by a previous operator.

- **Heading Section** - contains general information about the flight, including several fields that uniquely identify the DFL. Figure 6 illustrates a typical Heading Section.



DAILY FLIGHT LOG AND LOAD MANIFEST (Page 1)

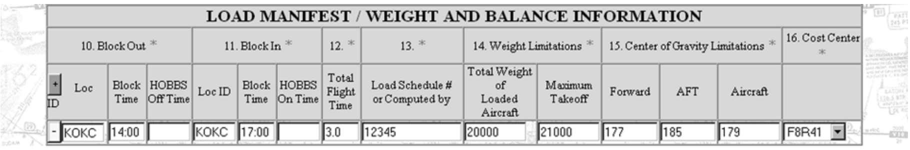
1. AIRCRAFT NO. *	2. AIRCRAFT TYPE	3. DATE *	DAILY FLIGHT LOG AND LOAD MANIFEST
N76	BE-300F	09/10/1999	

FLIGHT DATA

4. PILOT IN COMMAND *	5. NO. OF PASSENGERS	6. FUNCTION	7. TOTAL TIME IN SVC.	8. TOTAL FLT TIME *	9. ACFT TIME AFTER LAST FLIGHT
BRASIEL,RICHARD,J.		F	0.0	3.0	

Figure 6. DFL Page 1, Heading Section

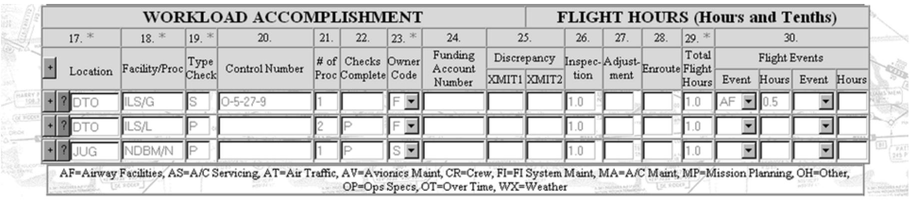
- **Load Manifest and Weight & Balance Information Section** - provides flight information for each flight leg flown during the DFL duty day. Figure 7 illustrates the Load Manifest section with a typical flight leg displayed. If the aircraft was released and arrived using the Dispatch system then the flight leg will be added to the Load Manifest section automatically. When creating a manual DFL the legs need to be added by the user.



LOAD MANIFEST / WEIGHT AND BALANCE INFORMATION													
10. Block Out *			11. Block In *			12. *	13. *	14. Weight Limitations *		15. Center of Gravity Limitations *			16. Cost Center *
Loc ID	Block Time	HOBBS Off Time	Loc ID	Block Time	HOBBS On Time	Total Flight Time	Load Schedule # or Computed by	Total Weight of Loaded Aircraft	Maximum Takeoff	Forward	AFT	Aircraft	
KOKC	14:00		KOKC	17:00		3.0	12345	20000	21000	177	185	179	F8R41

Figure 7. DFL Page 1, Load Manifest and Weight and Balance Section

- **Workload Accomplishment Section** - provides inspection information for each facility inspected during the DFL duty day. Figure 8 illustrates the Workload Accomplishment section with several typical Workload Accomplishment Records (WARs) displayed.



WORKLOAD ACCOMPLISHMENT										FLIGHT HOURS (Hours and Tenths)							
17. *	18. *	19. *	20.	21.	22.	23. *	24.	25.		26.	27.	28.	29. *	30.			
Location	Facility/Proc	Type Check	Control Number	# of Proc	Checks Complete	Owner Code	Funding Account Number	Discrepancy		Inspec-tion	Adjust-ment	Enroute	Total Flight Hours	Flight Events			
								XMIT1	XMIT2					Event	Hours	Event	Hours
DTO	ILS/G	S	O-5-27-9	1		F				1.0			1.0	AF	0.5		
DTO	ILS/L	P		2	P	F				1.0			1.0				
JUG	NDBM/N	P		1	P	S				1.0			1.0				

AF=Airway Facilities, AS=A/C Servicing, AT=Air Traffic, AV=Avionics Maint, CR=Crew, FI=FI System Maint, MA=A/C Maint, MP=Mission Planning, OH=Other, OP=Ops Specs, OT=Over Time, WX=Weather

Figure 8. DFL Page 1, Workload Accomplishment Section

- **Crew Data Section** - provides flight hour, duty and operations information during the DFL duty day for each crew member. Figure 9 illustrates the Crew Data section with several typical crew member records displayed.

Once a DFL has been completely filled out and has been checked by all necessary Quality Control personnel, the DFL can be submitted to the CFMSS system for processing. This will cause the necessary calculations to be performed on the aircraft, crew and inspection information and the data will be propagated throughout the CFMSS and Flight Dispatch systems.

When the DFL is submitted, the CFMSS system verifies the validity of the information in the Workload Accomplishment section. If errors are detected the submission process will not complete and the WAR rows that are in error are displayed as red text.

After a successful DFL submission has been made, the corresponding data in the central database is automatically updated and re-calculated. The aircraft maintenance records are updated based on the information filled out in the Load Manifest and Weight & Balance Information Section of the DFL. Specifically, the Block Out and Block In times are used for aircraft maintenance records. Likewise, the crew rest period is adjusted by the data entered in the Crew Data Section of the DFL. Finally, the facility inspection due dates are re-computed in the database based on the flight inspection results which are recorded in the Workload Accomplishment Section of the DFL.

WORKLOAD ACCOMPLISHMENT										FLIGHT HOURS (Hours and Tenths)							
17. *	18. *	19. *	20.	21.	22.	23. *	24.	25.		26.	27.	28.	29. *	30.			
Location	Facility/Proc	Type Check	Control Number	# of Proc	Checks Complete	Owner Code	Funding Account Number	Discrepancy		Inspection	Adjustment	Enroute	Total Flight Hours	Flight Events			
								XMIT1	XMIT2					Event	Hours	Event	Hours
DTO	ILS/G	S	O-5-27-9	1		F				1.0			1.0	AF	0.5		
DTO	ILS/L	P		2	P	F				1.0			1.0				
JUG	NDBM/N	P		1	P	S				1.0			1.0				

AF=Airway Facilities, AS=A/C Servicing, AT=Air Traffic, AV=Avionics Maint, CR=Crew, FI=FI System Maint, MA=A/C Maint, MP=Mission Planning, OH=Other, OP=Ops Specs, OT=Over Time, WX=Weather

Figure 9. DFL Page 1, Crew Data Section

DATABASE ORGANIZATION AND CONTENT

The database stores the entire information that ties all the CFMSS components together. Due to the large amount of data to be managed and processed, the database has been organized into three separate schemas:

- **AIRNAV** schema contains parameters for each facility, airport, approach procedures (including GPS) which require commissioning and inspections on a regular schedule.
- **CFMSS** schema contains facility description information, pending periodic and special inspection requests, and completed (historical) inspection requests. The inspection due dates, which are computed from the DFL Workload Accomplishment Section entries, are represented as a time window with an early and late date. This schema also contains the «contact» data which includes:
  - Names and phone numbers of airport personnel and FBO's.
  - Available contract fuel sources.
  - Hotels and other information in cities where flight inspection crew may land.
- MAINTENANCE AND TRAINING schema includes:

  Aircraft status which consists of:
  - List of all aircraft by tail number and FIFO assignment which are available for flight inspection
  - Maintenance schedule
  - Capability of each aircraft to perform flight inspection mission

Crew personnel information which consists of:

- Records of crew training and medical status
- Rest periods based on previous duty day

CONCLUSION

The entire system that has been described in this paper has been fully operational since December 1999. The complexity of the system and the size of the database required a long development and integration effort by both the FAA and the contractor. This project has been planned by the FAA as a incremental implementation with the scheduling system being deployed first by geographic areas. Finally, the entire East Coast of the US was integrated as a proof-of-concept, continuously refining and enhancing the scheduling operation. The final step was an incremental implementation of each FIFO into the centralized automated scheduling function.

In parallel was a test bed set up for integrating and testing the DFL, functioning with the dispatch/flight following system and all database schemas. During the validation phase, user interface and performance improvements were continuously applied. After an extensive testing period, the entire system was brought on line and operation started in a matter of days. The final success of this effort can only be attributed to the excellent cooperation of all parties involved and the motivation and enthusiasm of the FICO personnel to make the system work and meet the original mission statement.

With the realization of the CFMSS system, FICO now serves as a focal point for planning, scheduling, coordinating, dispatching, and tracking FAA aircraft conducting world-wide flight inspection activities. FICO, by overseeing the utilization of flight inspection aircraft and crew members assigned internationally and within the National Airspace System, is maximizing the efficiency of flight hour usage. And most important, flight safety has been enhanced by ensuring that the crew and aircraft are in compliance with FAA FAR, Part 135 requirements.

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FLIGHT INSPECTION SERVICES - BUSINESS STRATEGIES FOR THE MILLENNIUM

ABSTRACT

Flight Inspection (FI) services are still provided mainly by the public or not-for-profit sector, but are encountering the influences of privatisation, competition and contractorisation. There is consequently an increasing need to understand and use the techniques of strategic and operational management. This paper introduces those techniques and takes account of the practical experience of the authors.

The paper has three strands, which together form a forward-looking business review:
• Analysing the current position
• The process of change
• Maintaining the improvement.

The paper concludes with a plea for all-round managerial competence, emphasising that technical excellence will be of little use if business foundations crumble through neglect. An Annex of Management Ratios is provided.

INTRODUCTION

As we enter the new Millennium, we observe that, throughout the world, the majority of Flight Inspection (FI) services are still provided by the public or not-for-profit sector, either civil or military, but that three influences are causing that position to change quickly. Those influences are
• Political attitudes promoting full privatisation
• Competition from private sector service suppliers
• Trends toward full or partial contractorisation, without change of ownership.

In consequence, remaining NFP (not-for-profit) FI service providers increasingly need to look to the techniques of strategic and operational management, in order to
• Ensure future economic survival and gain necessary investment
• Remove, or defend themselves against the accusation of retaining, hidden cross-subsidies
• Compete effectively, but on a level playing field, with private enterprise
• Assess objectively the costs and benefits of contracting out all or part of their services
all while maintaining, at the very least, proper standards of safety, service and customer relations.

The purpose of this paper is to identify and exemplify the techniques which help providers carry out the necessary evaluation and implementation. The authors have taken account of examples in their own experience **[1,2]** using them to highlight good practice to follow and common pitfalls to avoid.

FORMAT OF THIS PAPER

This paper and its accompanying presentation will develop along three strands, reflecting the components of a forward looking business review, covering assessment and strategy formulation. The three strands are:

1. Analysing the current position: a structured review technique for identifying strengths, weaknesses and needs for change
2. The process of change: strategic planning and performance indicators
3. Maintaining the improvement: controlling operations by paired ratios.

ANALYSING THE CURRENT POSITION

No successful analysis can proceed effectively without some type of frame of reference or format to guide the work and place results in context. One well known example of such a format is the «Balanced Scorecard» of Kaplan and Norton **[3,4]** which has been used successfully for a number of years. However, in December 1999, the first CIMA Visiting Professor, Regina Herzlinger of Harvard University, gave a presentation at Edinburgh in which she outlined her own later published technique, more specifically aimed at effective oversight of the NFP sector, called the «Four by Four Review» **[5,6]**. The authors are very grateful to Professor Herzlinger, to CIMA and to Harvard University, for the opportunity to use the «Four by Four» method to structure the example analysis in this paper.

The «Four by Four» Concept

The Four by Four concept identifies four constituencies:

- Donors
- Clients
- Staff
- Society

and for each constituency poses four questions, covering

- Goals (the effectiveness and efficiency of achievement)
- Inter-Generational Equity or IGE (are resources being consumed now at the expense of the future?)
- Matching (ensuring that, for example, long-term projects are provided for out of long-term not short-term resources)
- Diversification (are resources sufficiently diverse to be sustainable in the longer term?).

The result is a sixteen-element, four by four matrix of questions and answers.

Applying the Concept to FI Services

For the purposes of this paper, we propose to define the constituencies in the following way:

- Donors - those (e g the state, through Civil or Military aviation organisations) who provide reserve revenue and capital funding for FI
- Clients - *customers* (e g airports/airfields/ airbases) who directly receive the service and pay up-front charges to recover costs
- Staff - operational and managerial employees
- Society - *consumers* (the «flying public») who indirectly benefit from the service in the form of safety assurance, even though they may be unaware of it.

The following four sections give examples of the types of questions which FI management should consider on behalf of all constituencies, ideally as part of a structured benchmarking exercise against similar organisations, competitors and (where available) published statistics and performance indicators.

Asking the questions - Donors

- **Goals:** Are the short and long term goals of donors clearly expressed and understood? If they are, what systems (e g performance metrics) exist to monitor and report on achievement?
- **IGE:** Are the interests of current and future funders even-handedly represented? For example is failure to plan for future investment/ excessive reliance on expensive, outdated methods consuming donors' resources now

and storing up trouble for the future?

- **Matching**: Is it certain that donors' funds have been allocated properly between current and longer-term expenditures? Do state budgeting arrangements allow fund allocation beyond the fiscal year? How does that affect planning?
- **Diversification**: In the state sector there may be no funding diversification at all. How risky is this to future service? Have other sources of funds (e g leasing) or of cost reduction (e g use of contractors) been properly appraised?

Asking the questions - Clients

- **Goals:** What awareness is there of the goals of clients, both as a group and individually? What customer relations/marketing strategy is in place to determine them? How well are standards of service being met? What value-for-money criteria are being applied to evaluate quality of service versus costs charged?
- **IGE:** Are clients and service provider working together to plan for the future (e g for technical developments/new equipment needs)? Does the service provider undertake to retain capability to service older equipment, so that the client is not forced into premature investment?
- **Matching:** Do costs recharged truly reflect long-run costs (e g of future replacements)? Are charges properly related to types/ standards of ground equipment in use? Are charges matched to hours spent on site, or to tasks completed? Does the client have a choice over this?
- **Diversification:** Does the client have a choice of service provider? In a monopoly-provider case, what chances of diversification are available? What diversification is available in (for example) methods of working, to reflect clients' individual needs?

Asking the questions - Staff

- **Goals:** How effectively are the group and personal goals of the staff being met? Are salary levels sufficiently market-related to prevent excessive and expensive staff turnover? What personal and professional training/growth opportunities are open to employees? What is the organisation's career structure?
- **IGE:** Are all staff treated equally irrespective of age/length of service? Is promotion on service or merit? Do new arrivals enjoy the same standards/rights as older hands?
- **Matching:** Is the set of qualifications/ experience held by the staff properly matched to technical/business requirements? Is the number of specialists/generalists truly matched to current and future needs? What recruitment/ appraisal/training systems exist to ensure future needs can be met?
- **Diversification:** What range of backgrounds exists within the staff? Are personnel recruited from a wide range of sources, or just a few (e g armed services)? Are diversity/equal opportunity standards met? Do systems exist to promote interchange/career development throughout the organisation?

Asking the questions - Society

- **Goals:** What steps have been taken to promote awareness and thus determine proper goals of society at large? How effectively are current safety standards maintained? What research is being carried out into enhancing standards/reducing operating costs/preparing for newer technologies? Are operations organised to minimise public inconvenience (e g by night flying to prevent disruptions to daytime services)?
- **IGE:** Is service provision structured to prevent excessive subsidies which mortgage future revenues? What provision is made for appraisal of future public needs and the equipment/working methods needed to answer them? Are the most economical methods of working (including contracting) being operated in order to ensure losses are not built up for the future?
- **Matching:** If funds are raised publicly (e g through taxation) are long and short-term

needs matched? If charges are levied, do they relate to standards of service/variable time horizons)? Are replacement strategies (for aircraft and equipment) sufficiently robust, and competent to provide best public value?

- **Diversification:** Are the sources of service provision sufficiently diverse (e g state, private sector, contractor) to ensure maintenance of standards, continuity of service, and best value through price competition? Is the provision of new and replacement equipment also sufficiently diverse to give best service and value (ie is commercially available equipment appraised before choosing in-house development by the service provider, which may not be technologically state-of-the-art)?

THE PROCESS OF CHANGE

There is no point in carrying out an assessment exercise without being prepared to set and carry out a change process to remedy imperfections, grasp opportunities and set course for future success. The process of change involves a series of steps, as follows:

1. **Benchmarking** - versus competitors' operations or known standards
2. **Comparison** - with existing operations
3. **Determination** - of feasible objectives
4. **Design** - of new processes, products or services
5. **Planning** - of the operational changes
6. **Implementation** - of the change process, to completion
7. **Recalibration** - of the original strategy in the light of the results achieved.

In an effective and developing organisation, change will of course be a continuous process, not a one-off exercise!

The analysis described above, if done effectively, should take care of steps 1 and 2, and lead thinking towards 3. The remainder of this paper will therefore concern itself with stages 4 to 7 - strategies and operations.

Performance Indicators and Three (or Four) E's

Almost all stages of the process of change will involve the use of some form of performance measurement using ratio-based indicators. Indicators will be necessary for

1. Assessment of the present position - benchmarking and comparison by using financial and operating ratios
2. Determining objectives, designing processes/ products/services, and planning the necessary changes - deriving Critical Success Factors (CSFs) to influence
3. Implementing those changes, by strategic plan and/or capital investment - monitoring the progress of change in the numerical values of the CSFs
4. Evaluating the actual results and recalibrating the strategy - were the final numerical values of the CSFs as predicted in the strategic plan or project appraisal?

It is necessary, if ratios are to be used properly and wisely, to understand the rationale of Process Analysis and the need for balance in the use of Indicators. A useful form of process analysis involves the «Three E's» - Economy, Efficiency and Effectiveness - to give a start-to-finish process coverage. Many people talk about these Three E's but few can correctly define them. For the record, this is how they should be expressed and used:

- **Economy** relates to inputs, and is the obtaining of resources of appropriate quality at least cost
- **Efficiency** relates to the operation or business process itself, and is the gaining of maximum output from those inputs (ie it is relative productivity)
- **Effectiveness** relates to outputs, and is the extent to which the products of the process achieve the desired objectives; it is a quality measure.

Optimisation of the business process implies optimisation of all three elements - but if improvements, results and especially motivation are to be sustained, any management must pay special attention to the «Fourth E» - Equity:

- **Equity** ensures that the benefits of improvement are shared among *all* those whose efforts led to the achievement, *including* clients. Retention of benefit, material or honorary, by owners or senior management alone, is in the long run always self-defeating.

In order to ensure balance in setting performance indicators, it is wise to use «countervailing pairs», where one indicator covers cost (economy and efficiency) and the other quality. If, for example, there is an issue of aircraft availability versus maintenance expenditure, a «pair» could be expressed as:

* Aircraft hours actually available as % of theoretically available
* Maintenance costs actually incurred as % of budgeted..

Simple graphical analysis can then be used to determine the trends of availability and cost, determine the form of any relationship, and attempt to achieve the optimal balance. This paper gives at Annex A numerous examples of common ratio pairs from which FI management may choose those most appropriate to their control needs; many more exist **[7].**

Performance Indicators and Strategic Planning

Many organisations believe themselves to have a strategic business plan when all they have actually done is define some theoretical «objectives» and then group under those headings the activities which they are already carrying out. To make matters worse, it is often unclear whether numerical values assigned to objectives are short-term or long-term, for one year or the whole planning period.

For an effective action plan, the following steps are needed:

1. Define a consistent set of quantifiable, measurable objectives - *where you want to go*
2. For each objective, define verbally the Critical Success Factors (CSF) - *what you have to change/influence to get there*
3. For each CSF, derive the formula for the Performance Indicator (PI) to measure - *how you work it out*
4. For each PI, set the target value you need to achieve in the short-term and at the end of the planning period - *and compare with current or benchmark value.*

Note that it is only at Step 4 that numerical values begin to be assigned.

Examples

1. *Objective 1*: To become the major FI service nationally by Year 2005 while improving financial returns
2. *CSFs*: Market share; net profit
3. *PIs*: (1) Number of contracts as % total available; (2) return as % of net assets employed
4. *Numerical Values:*

	Current	Year 1	Year 5
	%	%	%
PI (1)	40	45	55
PI (2)	5	7	11

1. *Objective 2:* To maximise task availability of aircraft while controlling maintenance costs
2. *CSFs:* Available hours/total hours; maintenance expenditure
3. *PIs:* (1) Task hours as % total hours; (2) maintenance costs as % current level
4. *Numerical Values:*

	Current	Year 1	Year 5
	%	%	%
PI(1)	50	55	70
PI(2)	100	95	80

From these will follow subsidiary objectives and indicators, leading to a consistent set of actions necessary to be followed in order to achieve the overall strategic objective. The numerical values of the PIs provide a clear measure of progress during the plan period, and allow reconsideration or recalibration of the strategy if actual performance begins to drift from planned.

MAINTAINING IMPROVEMENT: APPLICATION OF THE FOUR E's IN FI OPERATIONS

Having dealt with the definition of the Four E's, and shown the use of PIs in the defining and monitoring of strategy, it is useful to conclude by giving some specific examples of their use in day-to-day operational management. It will be noticed that, although each element is dealt with separately, many topics involve more than one criterion.

Economy (*costs of input resources*)

- Assets: Evaluate the full costs of operating, maintaining and supporting aircraft and flight inspection equipment. Question the need and/ or justification for upgrade or replacement. Is it possible to make a financial case for investment in newer aircraft for cost reduction purposes? If a newer aircraft is justifiable, can a case be made for purchase and installation of new FI equipment, taking account of the need to hire back-up aircraft during the inevitable downtime? As an alternative to investment, or if it cannot be justified, could cost savings be achieved by outsourcing to a specialist FI contractor?
- Staff: Review to ensure that there are no cases of over-staffing, over-qualification or overpayment. Ensure that staff are employed appropriately, and that the most expensive staff justify their employment. Could they be replaced by contractors, who may charge a higher unit rate but do not incur the costs of permanent staff in terms of pension liabilities, holiday payments, etc.?
- Maintenance: Review the terms of employment of the aircraft maintenance contractor: unit price or cost-plus hourly rate - which is more appropriate? Does the contractor purchase spares and charge out at mark-up? If so, is direct purchase by the unit's own contract supervisor/co-ordinator more economic, taking account of staff time and storage costs?

Efficiency (*converting inputs to outputs*)

Evaluate staff and equipment usage to ensure optimum capacity utilisation, by asking questions such as:

- Are high-cost aircrew rostered to make full use of flying hours/crew duty time?
- Are crew contracts written so as to ensure flexibility over weekend and night working, plus variable length duty days, while minimising overtime payments?
- Are transit/positioning/ferry hours minimised by maximising off-base detachment working?
- Can a simulator, rather than an aircraft, be utilised to ensure pilot recency in the most efficient manner?
- Are aircraft maintenance turnaround times minimised by using a specialist contractor for period deep maintenance work?
- Is the impact of local air traffic delays during calibration flying monitored and controlled?
- Are the factors of aircraft tasking availability and no-shows at the customer's facility investigated, monitored and controlled?

Effectiveness (*quality of outputs produced*)

Assess and evaluate quality of service to customers using some or all of the following questions:

- What surveys are carried out into customer satisfaction, what are the results, and are those results adequately acted upon?
- What percentage of contracts are renewed, and what is the current market share?
- Are contract prices rising, or is market share having to be bought by discounting?
- What training has been given to staff in customer awareness and customer focus, in order to ensure elimination of the «official Inspection» frame of mind?
- What service reliability (in terms of percentage of inspections cancelled for reasons other than adverse weather) is being achieved?
- Are all navaids flight checked within their allowable inspection periods without calling for extensions from the safety regulator?
- What is the average response time to emergency call-outs?

Equity (sharing the benefits of improvement with customers and stakeholders)

Opportunities for benefit sharing should be sought as a matter of good practice and customer retention. Examples might be:

- Can inspections for a number of customers be combined in a single campaign (eg military and civil), minimising overall transit/ferry flying hours and thus reducing total cost to each?
- Does the FI organisation see any economic incentive in reducing flying hours to individual customers?
- Has the FI organisation the confidence to reward a long-term customer revenue stream by investing for future efficiency gains, sharing the resulting savings by maintaining or reducing charges?
- Where staff have contributed, by improved working practices, to gains in profit or market share, are the benefits of those gains shared through bonus payments, profit-sharing or other reward schemes?
- Has the FI organisation fully evaluated (as it should, in fairness to all parties) the scope for using contract partnering to achieve savings, the benefits which could be shared with the customer through reduced charges?

CONCLUSION

The authors have sought in this paper to pass on the fruits of their experience in flight inspection from the viewpoints of the technical operator and the business manager, and hope that they have demonstrated that those viewpoints are in reality compatible. If they have succeeded in reducing by even the smallest amount the mutual suspicion of engineer and accountant, their efforts will have been more than fully rewarded.

Safety and service are the reasons for the existence of the FI operation; they are not excuses for mortgaging its future by neglecting its management.

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ANNEX A

MANAGEMENT RATIOS FOR FI BUSINESS OPERATIONS

(Note: Many of these ratios will find application in other aviation services businesses. Conversely, experienced FI operators will be able to suggest numerous additional indicators)

Financial Performance - Revenue

1. Return on total income (net profit as % sales)
2. Total asset turnover (turnover as % total capital assets)

3. Total annual cost of operation ($/year)
4. Best annual contractor's quotation ($/year)

5. Proportion of total costs recovered through direct charging («self-funding ratio») (%)
6. Average customer charges in relation to local/ national/international benchmark levels (%)

7. Average time allowance for customer payment (days/customer)
8. Finance/interest charges in relation to total costs (%)

Financial Performance - Capital Investment

9. Average life expectancy of fixed assets (years or % original life)
10. Annual new/replacement capital expenditure ($ total or % asset value)

11. Technical assets within (for example) two years of obsolescence (% total by number or value)
12. Expenditure on R&D in relation to total costs (%)

Customers

13. Number of contracts gained (or retained) as % of previous total
14. Average income per contract as % of previous year figure

15. Total increase in customers/contracts (% of previous year)
16. Total cost of publicity/advertising/customer liaison ($ total or $/customer)
17. Number of favourable or satisfactory responses to customer surveys (% customers surveyed)
18. Average expenditure per customer ($/customer)

Operations

19. Average productive availability of capital equipment (% total hours)
20. Maintenance expenditure per operating hour ($/hour)

21. Total cost (revenue and capital charges) of capital equipment operation ($/year)
22. Quoted operating hire/contract charges ($/year)

23. Effective total cost of assets per productive hour ($/hr)
24. Comparable all-in contract costs ($/hr)

25. Positioning/transit/ferry hrs relative to total (%)
26. Annual costs of detachment working ($/year)

27. Fuel purchase contracts/supply source visits (no./sortie or no./year)
28. Fuel costs per operating hour ($/hr)

29. Average total flying hours per customer inspection visit ($/event)
30. Average number of visits per sortie (no./trip)

Staff

31. Revenue earning person-hours in relation to total working person-hours (%)
32. Costs of professional/flying staff in relation to total staff costs (%)

33. Annual profits in relation to previous year (%)
34. Profit-sharing pay-out through staff bonus/ benefit schemes (% of total salary costs)

35. Average productive hours per staff member (hrs/person/year)
36. Total remuneration cost per person, including overtime, bonus, etc ($/hr or $/year)

37. Average annual staff turnover (%)
38. Average staff salary levels in relation to market benchmarks (%)

39. Unproductive asset and staff time (% of total)
40. Cost of administrative/scheduling staff members (%of total staff cost)

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