

INTERNATIONAL CIVIL AVIATION ORGANIZATION

**RLA/00/009 PROJECT COORDINATION MEETING ON GNSS AUGMENTATION
TRIALS**

(Santiago, 1 to 3 August 2001)

Agenda Item 2: Analysis of the activities contemplated in the GNSS Regional Augmentation Project

(Presented by the Secretariat)

Summary

This working paper presents, for analysis, the types of trials, as well as the objectives and trial plans taken into consideration in the RLA/00/009 Regional Augmentation Project.

Reference:

RLA /00/009 Project Document (Regional GNSS Augmentation Trials).

1. Background

1.1 The main activity of the Project is to collect data permitting to examine the precision, availability, continuity and integrity parameters, as well as to execute a CAR/SAM Regional and State plan to carry out a flight test, with a navigation and satellite augmentation system (GPS/WAAS). For each of these plans, the Project describes the platform of the ground and air segment, the trials to execute, verifies the precision, integrity, availability and continuity parameters for the en-route, precision and non precision approach flight phases, and outlines the results expected.

1.2 The ground and air segment platform to provide augmentation of the GPS signal is described under Agenda Item 1. With respect to the trials to execute, these will be carried out over en-route and precision and non precision approach flights. For each of these trials, the horizontal and vertical precision will be determined and compared with the accepted minimum operational performance standards, and the integrity and availability of the GPS and augmentation signals will be determined.

1.3 The results of the regional and State trials will consist in the development of a report analysing the trial outcome, as well as of an appreciation as to whether the objectives of the flight tests have been complied with.

2. **Analysis**

2.1 For the execution of regional and State trials, it would be necessary to analyse the information in **Appendix A** to this paper, as well as elaborate a chronogram for same. Moreover, an analysis should be made to activities such as continuous compilation of data and how this is affected by the ionosphere, as well as other factors of importance.

2.2 For the verification as to whether the results of the trials respond to pre-determined values of exactness and availability for precision and non-precision approach, the determination of the level of the services foreseen is required, specifying the network of reference stations described under Agenda Item 1, and, at the same time, show it in graphic form. An example of this, but through another configuration, is shown in Appendix X to RLA/00/009 Project Document.

2.3 **Appendix B** to this paper presents, for your review, State and regional objectives and flight tests that include previous activities to be carried out, precision approach requirements, requirements for the compilation of flight data and reduction and data analysis.

3. **Action suggested**

3.1 The meeting is invited to:

- a) Note the information provided in this working paper;
- b) Analyze the trial master sample in Appendix A to this paper, defining a chronogram for its execution; and
- c) Analyze the objectives, as well as the trial plans shown in Appendix B to this paper.

MASTER TRIAL SAMPLE

STATES TRIAL TYPES	STATE A	STATE B	STATE C	STATE D	STATE E	STATE F	STATE G
1	2	3	4	5	6	7	8
Ground en- route							
En-route over oceanic area							
Non precision approach							
CAT I							
CAT I with vertical guide							
Maneuvers in terminal area							
Closed loop (CAT I without TRS)							

Mark in the appropriate box the date of the scheduled trial.

TEST OBJECTIVES AND ACTIVITIES

1. Test Objectives

1.1 Objectives of regional flight tests include:

- Demonstrate efforts toward seamless GNSS operation.
- Demonstrate expansion of service volume through international participation.
- Demonstrate that international GNSS compatibility is technically achievable.
- Demonstrate that, with vertical guidance, precision approaches can be performed in Caribbean and South America using GPS-augmented signals broadcast from a wide area augmentation system.
- Measure the system accuracy and message performance via ground and flight tests in the Region, for the following applications, as appropriate:
 - Long term performance data at local reference stations
 - Precision approaches at selected airports
 - Non-precision approaches and non-precision approaches with vertical guidance
 - Category I approaches
 - Category I approaches in a country where no reference station is located (Closed-loop test)
 - Terminal area maneuvers at selected airports
 - En route routes over land areas
 - En route routes over oceanic areas.
- Test SIDS and STARS at some selected locations to demonstrate a seamless takeoff to landing capability.
- Increase international understanding for sharing information between independent GPS augmentation systems, and the shared use of communication satellites.
- Promote international acceptance and use of augmented GPS in civil aviation applications.
- Collect and analyze operational performance of the wide area augmentation system with focus on feasibility of using a Wide Area Differential GPS System in the CAR/SAM region.
- Foster international cooperation and contribute to the safety of the global transportation system through sharing of information, technologies, data, technical assistance, and training between countries and non-governmental agencies.
- Encourage future Satellite-Based Augmentation System (SBAS) flight tests.

2. Test Activities

The activities of the flight tests are divided into three phases: pre-test, execution and post-test. The following sections describe in detail the activities associated with each of the phases.

2.1 **Pre-Test activities**

The Pre-Test activities span a wide range of tasks centered on verifying performance and availability of hardware, software, and communications to support test execution and post-test activities. Pre-test activities include:

- Verifying operation of the CSTB system.
- Verifying availability and operation of an aircraft.
- Verifying that the data collection capability is in place.
- If GEO broadcast is to be used, test communications between the CSTB TMS and the identified CSTB uplink facility and insure GEO broadcast availability.
- Testing ground-to-air VHF communications link.
- Performing surveys of the runway thresholds of the airport.
- Verifying that all phone lines and other communications are established.
- Installing and testing ground support and demonstration equipment.

2.2 **Test Execution**

The Precision Approach demonstration will consist of repeated precision approaches into the airport. Data will be collected from UPs monitoring available signals from the GEOs or VHF broadcasts, depending on availability.

2.2.1 ***Precision Approach Requirements***

The requirements for conducting precision approaches into the airport are as follows:

- An ILS Overlay procedure will be used during the CAT I approach. GPS data will be displayed on one cockpit display, which will provide guidance for landing; ILS data will be displayed on the other cockpit display for backup and safety.
- Tests will be conducted in daytime VFR conditions.
- Although no specific GPS constellation or dilution-of-precision geometry (DOP) requirements are required, data should be excluded from the accuracy analysis when it is collected during periods that DOP requirements are not met or when differential corrections are not available for the GPS satellites in use.

2.2.2 **Test Data Collection Requirements**

2.2.2.1 ***Aircraft Data Collection***

The following data will be recorded on board the aircraft. All data will be time-stamped using the on board time code generator to a resolution of milliseconds:

- UP Health, Status, and Flags.
- GPS x,y,z Position, Velocity, and Acceleration data, GPS Clock Error and Clock Drift, GPS Position error (North, East, and Up), GPS Dilution Of Precision (vdop, hdop, and pdop), and RAIM ARP.

- GPS Integrity Message - Satellite ID, time of validity, time of SV fail, time of Navigation fail, time of SV OK, and time failed set returned to use.
- SV Constellation message - SV used for solution, time of validity, time of correction, pseudorange correction, pseudorange rate correction, IODE 0-255 number, uncorrected pseudorange, uncorrected carrier phase, pseudorange smoothing factor, ionospheric error estimate, tropospheric error estimate, signal-to-noise measurement, SV elevation, SV Azimuth angle, SV use flag.
- CSTB wide area data broadcast - 250 bit (500 symbol) message.
- Aircraft Navigation and Guidance information - INS data, Baro altimeter data, glide slope data, DME data, project guidance flag, navigation filter flag, GPS data flag, and GPS correction flag.

2.2.2.2 Test Bed Wide Area Master Station Data Collection

The TMS will record data from each TRS in use. This data will include:

- GPS data for each satellite in view will include L1-C/A code pseudorange measurements, L1 carrier range measurements, L2-L1 raw pseudorange measurements, L2-L1 differential range measurements.

In addition to recording data input from the TRSs described above, the TMS will record the following data:

- Outgoing wide area augmentation Data Broadcast messages;
- GEO ephemeris information;
- System clock biases; and
- Event logs from the TMS, TRS, and Earth Station processor.

2.2.2.3 TSPI Data Collection

TSPI data (position and time) will be recorded during the precision landing portion of the demonstration. TSPI L1/L2 data will also be collected to serve as a reference for the ionosphere model.

2.3 Post-Test Activities

The Post-Test activities consist of data reduction and analysis, and preparing a flight test report.

2.3.1 Test Data Reduction and Analysis

The purpose of these tests is to acquire data related to the accuracy and integrity of a seamless, integrated international augmentation system.

The data reduction and analysis tasks are:

- Compare GPS Sensor position to the TSPI truth source to determine navigation sensor error (NSE);

- Distribute the sensor error to cause, including clock error, ephemeral error, ionospheric error, and tropospheric error;
- Determine Flight Technical Error (FTE);
- Determine Total System Error (TSE); and
- Determine the extent of wide area augmentation system seamless coverage provided by a CSTB wide area augmentation system, including the navigation SIS broadcast bit error rate, message error rate, signal availability, comparative accuracy, comparative integrity, comparative availability and joint availability analysis.

2.3.1.1 **Navigation Sensor Error Reduction and Analysis**

Navigation sensor error (NSE) is defined as the difference between the wide area augmentation system position solution and the true position. NSE will be determined by comparing position estimated by the wide area augmentation system, to aircraft position provided by the TSPI system. Differences will be analyzed for mean offsets, the standards deviation of the offsets, and the distribution of the offsets (i.e., Gaussian or other). Navigation sensor error will be decomposed into uncorrected navigation clock errors, ephemeral errors, ionospheric errors, and tropospheric errors.

2.3.1.2 **Flight Technical Error**

Flight technical error (FTE) is defined as the difference between the wide area augmentation system position solution and the expected position along the glidepath. FTE will be determined by analyzing the aircraft guidance information presented to the pilot (i.e., needle deviations converted into distance). The data will be analyzed for mean offsets, the standards deviation of the offsets, and the distribution of the offsets (i.e., Gaussian or other).

2.3.1.3 **Total System Error**

Total system error (TSE) is defined as the sum of NSE and FTE, and is computed by differentiating the true position from the expected position along the glidepath. TSE will be determined by comparing the aircraft position provided by the TSPI to the calculated glidepath.

2.3.1.4 **GNSS Seamless Coverage**

The Navigation signal data from the GEO satellite will be analyzed to determine the availability of the signal. Transmitted and received messages will be compared to determine the bit error and message error rates. The integrity of the broadcast will also be analyzed.

2.3.2 **Test Report**

Final activity is the development of a flight test report. The report will present results of the test data analysis and an assessment of whether the flight test objectives were met.