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Approaching Nice with the EGNOS System Test Bed

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Summary

The EGNOS System currently under development by the European Space Agency (ESA) is expected to reach its operational capability by 2004. As a part of its commitment to the European Tripartite Agreement between the Commission of the European Union, the European Space Agency and Eurocontrol, Eurocontrol is responsible for the co-ordination and execution of various activities related to the operational validation of EGNOS.

EGNOS is designed, among other things, to meet the requirements of both Precision Approach and RNAV Approach with Vertical Guidance, also known as LNAV/VNAV or APV. Work has started recently in the ICAO Obstacle Clearance Panel (OCP) to develop design criteria for approach procedures based on SBAS.

Eurocontrol, in co-operation with ESA and the French DGAC, initiated a simulation in a transport flight simulator at a flight test centre (CEV) in Istres, south of France, to study EGNOS-based approaches on a specific approach procedure to the airport of Nice, France. The procedure was designed using recent ICAO OCP working material and assumes State-of-the-art capabilities of the on-board Flight Management System (FMS). Nice airport is a very interesting example of a location where the introduction of SBAS Systems may bring operational benefits.

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Summary

Following the simulation, as a part of the GOV (GNSS-1 Operational Validation) Working Group Activities, Eurocontrol has flight tested the procedure in real-life using a dedicated EGNOS receiver inside an experimental aircraft for both data collection and aircraft guidance.

This paper describes the set-up of the receiver and the FMS inside the aircraft for the curved and ILS-like approach procedure to Nice and provides a quick view of their influence on the control characteristics of the experimental aircraft. The results also include the performance of the ESTB (EGNOS System Test Bed) during the approaches. Finally, the experience of pilots flying the procedure are presented with a comparison to today's approach aids.

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Introduction

EGNOS, the European component of a Satellite-Based Augmentation System (SBAS) to GPS, is currently under development and is expected to be in operation in 2004. EUROCONTROL, as a part of its commitment to the European Tripartite Agreement with the Commission of the European Union and ESA, is responsible for the co-ordination of the operational validation of EGNOS for civil aviation.

Operational validation includes all activities that will contribute to showing that EGNOS is ready to be implemented to support the flight operations for which it is intended. The operational validation activities are co-ordinate through a group known as the ‘GNSS - 1 Operational Validation (GOV) Working Group, chaired by EUROCONTROL and primarily composed of European Air Traffic Service Providers intending to offer navigation services based on EGNOS.

One important activity within the GOV is to establish the type of operations that will be supported by EGNOS and based on this to develop an operational concept for the use of EGNOS by Civil Aviation in Europe.

Introduction

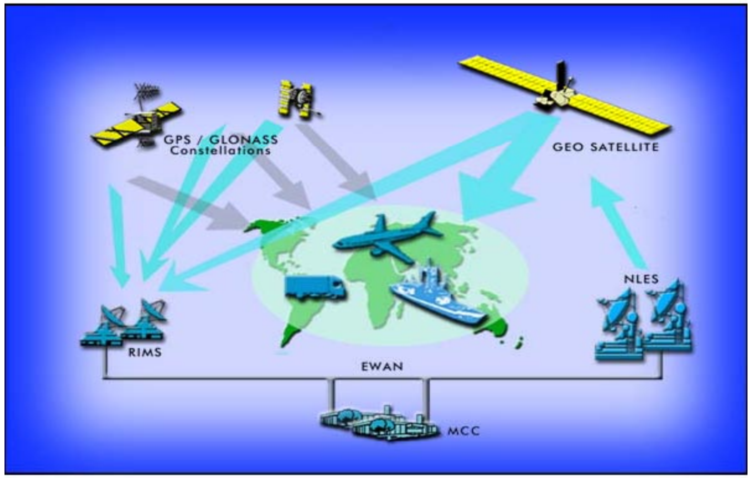
Experimental work plays a crucial role within the work carried out by the GOV. The current 'Early Trials' activities focus primarily on gathering experience with EGNOS using the EGNOS System Test Bed (ESTB). It includes development of prototype tools for static and onboard data collection and evaluation.

Trying to merge both technical and operational activities, EUROCONTROL in co-operation with ESA and the French DGAC, has flight tested in real-life, using a dedicated EGNOS receiver providing guidance, a specific approach procedure to the airport of Nice which could be considered as a curved Approach with Vertical guidance (APV).

The primary basis in European airspace for the management and introduction of aircraft operations and the associated navigation aids required is the EUROCONTROL Navigation Strategy for ECAC. The main driver for the Nav Strategy is the associated Area Navigation (RNAV) implementation strategy included in it. It is within the latter that EGNOS will play its role.

Area Navigation (RNAV): A method of navigation which permits aircraft operation on any desired flight path within the coverage of the station-referenced navigation aids or within the limits of the capability of self-contained aids, or a combination of these.[7]

The current planning is that Europe in the coming 15 years will transition to a pure RNAV-based environment, where only in the precision approach phase of flight the aircraft may continue to receive guidance related to the location of fixed aids such as ILS or MLS.



EGNOS System Architecture

EGNOS will, in principle, be an enabler for all RNAV operations.

Pre-flight

The accurate vertical guidance provided by EGNOS will provide some real benefits for the approach, missed approach and departure phases of flight. RNAV procedure design criteria that exist today in these phases of flight are only 2-D (therefore also known as Lateral NAV or LNAV).

In November 2001 the ICAO Obstacle Clearance Panel (OCP) will publish the first criteria for procedures giving credit to vertical guidance into the aircraft navigation system from the Baro-altimeter. Some people have initially argued that the criteria for LNAV, Baro-VNAV and ILS Cat-I are sufficient for the approach phase of flight. The FAA Order 8260.48 with WAAS approach design criteria illustrates this concept of operations. This approach minimises the complexity of the procedures design while accommodating aircraft with various types of onboard equipment.

It is believed that both, the improved horizontal and vertical guidance from SBAS could make a substantial difference. Firstly, the approach area width may be reduced and, secondly, the approach minima may be reduced. Furthermore, the availability of the near Cat-I performance of EGNOS over a wide area encourages the consideration of approaches outside the runway centreline, so called curved approaches, for which renewed interest exists given the increasing environmental concerns around airports.

Pre-flight

To evaluate the potential use of EGNOS for approaches where part of the Final Approach Segment (FAS) is not aligned with the runway centre line (also known as curved approaches) a simulation was performed of a specific approach procedure to Nice airport.The approach to Nice is a very interesting example where the introduction of curved RNAV approach procedures could bring environmental benefits.

The current choices in Nice are between a visual approach along the peninsula of Cap d'Antibes followed by a sharp unguided turn towards Runway04L. Due to the difficulty of flying this approach the minima are high.

minima: specified altitude below which descent must not be made without the required visual reference [7]

Under low-visibility conditions the alternative is an ILS Cat-I approach straight over the peninsula raising many complaints from local inhabitants.

SBAS could introduce a navigation capability that will make the curved approach more easily flyable by providing guidance all along the procedure. Furthermore it would avoid the need to fly over the peninsula even in more demanding meteorological conditions.

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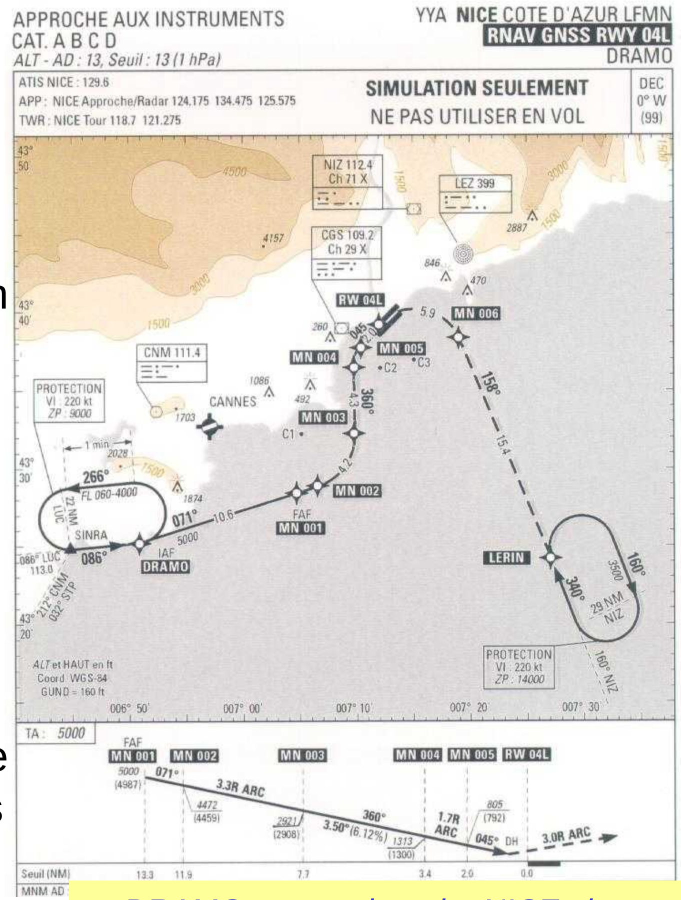
For the purpose of the simulation a procedure that modern aircraft are able to fly was designed by Yves Coutier of the French DGAC. Due to the unavailability of specific SBAS design criteria, working material of the ICAO OCP for Baro-VNAV was used in conjunction with ILS design criteria for the Final Approach Segment (FAS) and material developed in the early 90's for MLS-based curved approaches . This method was considered acceptable due to the absence of obstacles on the approach path. Important design aspects are related to the capability of the aircraft Flight Management System (FMS). The curves from waypoints MN002 to MN003 and from MN004 to MN005 are fixed-radius turns that only state-of-the-art FMSs are able to fly. Especially the second turn is sensitive to tailwind, which could cause difficulties when lining up for approach. The FAS includes the final turn and a reduced runway-aligned segment of 2 nautical miles (NM). This is only possible if the aircraft is flying the final turn in a stabilised approach configuration, which requires vertical guidance all along the approach path from a high integrity navigation aid such as EGNOS.



DRAMO approach to the NICE airport

Pre-flight

The simulation was performed in a commercial transport aircraft simulator with a cockpit lay-out based on the Airbus family that was operated by the French flight test facility (Centre d'Essais en Vol - CEV) in Istres.

For the simulation of the approach at Istres, an EGNOS error simulation operated at ESA Technical Centre (ESTEC) was used to generate a set of data representative of the Signal-In-Space (SIS) performance of both GPS alone and of EGNOS. Although well representative of the SIS the simulator was not able at that stage to take aircraft dynamics into account.

Another limitation during the simulations, was the fact that the Flight Simulator at Istres had a Flight Control Unit without the capability to fly fixed-radius turns. The guidance laws in the simulator 's FMS therefore were modified to allow an approximation of this capability.

Two main scenarios were studied for comparison:

- GPS alone with Baro-altimeter to capture the ILS, which is then used for landing
- EGNOS for the complete procedure

Pre-flight

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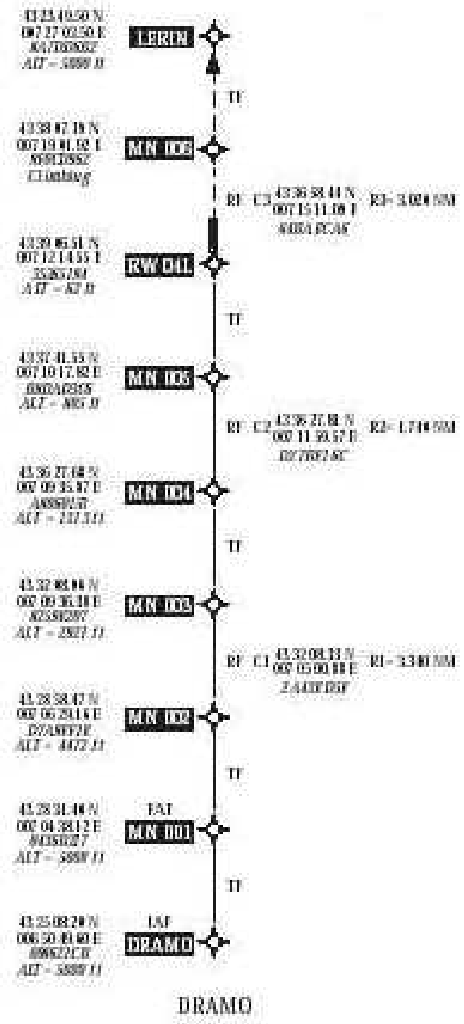
When performing the simulation, it quickly appeared that the first scenario was not possible since 2NM is too short a distance for engaging the ILS mode to allow for aircraft stabilisation. Only a navigation aid providing continuous guidance along the approach would allow the Nice procedure to be flown.

Flying the procedure using the second scenario under various wind conditions achieved satisfactory performance. In fact, it was found that the influence of the EGNOS error was not noticeable during the approach.

The main conclusion was therefore that the introduction of such a procedure would not be limited by the accuracy of the position error. Conditions for implementation would be, firstly, guarantees for the position accuracy through its integrity and, secondly, the capability of the aircraft in association with its FMS plus sufficient situational awareness for the pilot through appropriate displays.



In-flight

Following the work initiated with the approach simulations at Istres, EUROCONTROL decided to flight-test the procedure in real-life using a dedicated EGNOS receiver onboard an aircraft for both data collection and guidance.

For this purpose EUROCONTROL contracted the National Aerospace Laboratory (NLR) from the Netherlands to carry out the curved approaches as well as a series of ILS look-alike straight in approaches.

NLR 's Cessna Citation II aircraft, integrates a Research Flight Management (RFMS) that is fully programmable and able to accept data from various on-board systems. It includes a flight director feature, which when fed with EGNOS position data can provide curved approach guidance.

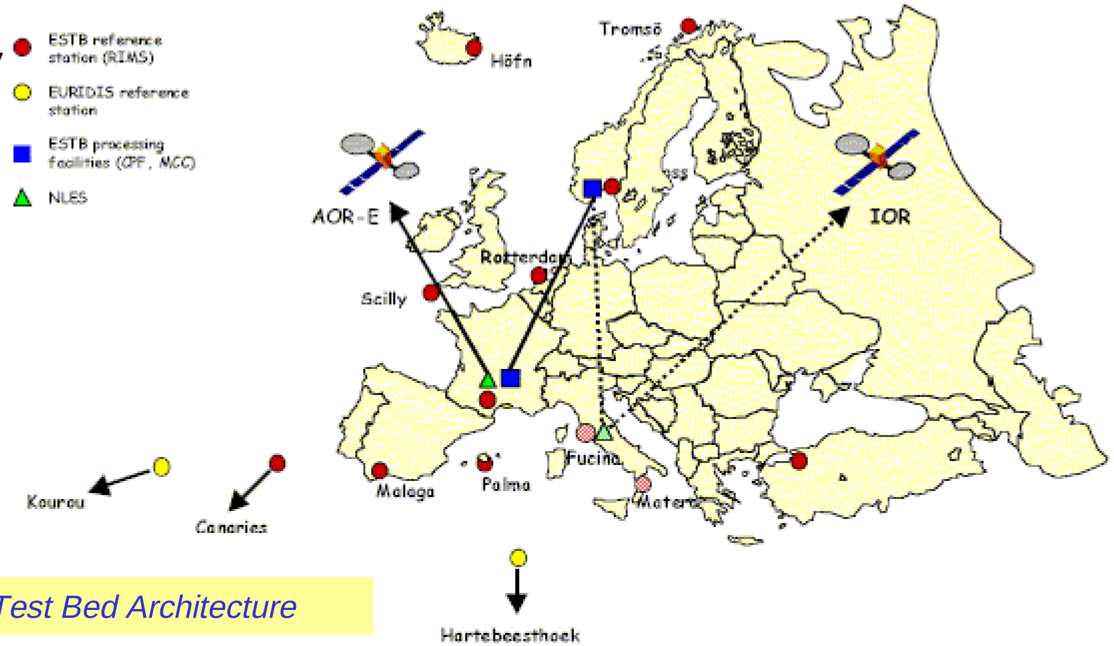
A total of 12 approaches at Nice airport were performed comprising:

- 3 Flight Director (F/D) guided straigth-in approaches
- 3 auto-pilot guided straight-in approaches
- 6 RFMS-F/D guided pre-defined curved approaches

Since February 2000 the EGNOS System Test Bed (ESTB) has been broadcasting over Europe. The ESTB is a complete EGNOS prototype and has recently been upgraded to be in line with RTCA MOPS Do-229A. *[4]*

The new ESTB configuration, called Version 1.1, has ten reference stations with Central Processing Facilities in Honefoss, Norway and Toulouse, France.

The ESTB signal is currently available from the AOR-E Inmarsat-III satellite.



EGNOS System Test Bed Architecture

NLR conducted the approaches using their Cessna Citation II research aircraft. In the framework of the FAST programme (Future Aircraft Systems Test-Bed), NLR has prepared the Citation aircraft for the integration and testing of ATM systems and concepts.

One important component of FAST is the Citation Removable Experimental Flight Deck, featuring high resolution LCD displays including:

- Fokker PFD
- Experimental Navigation Display
- 4D Flight-Director(F/D) Guidance
- 3D Auto-flight Guidance which enables coupling of experimental guidance instrumentation to the aircraft 's auto-pilot

Citation Removable Experimental Flght Deck

In-flight

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Another important component integrated in the NLR Cessna Citation II is the RFMS (Research Flight Management System), a fully programmable FMS able to accept data from various on-board systems.

NLR Cessna Citation II Research Flight Management System

Septentrio PolaRx-1: A new EGNOS receiver in Europe

Septentrio, a new European company developing GNSS receivers, provided a special version of their PolarRx-1 firmware able to provide, in real-time, ESTB-positioning and integrity data to the NLR Cessna Citation II RFMS.
PolaRx-1 is a 24-channel receiver that supports dual frequency GPS, GLONASS, EGNOS and WAAS satellite systems.

During the flights the PolaRx-1 was working on L1 single frequency, computing ESTB-enhanced position if both long-term and fast corrections were available from the AOR-E GEO satellite for at least 4 satellites in view. Otherwise GPS position was computed.

ESTB Ionospheric model was applied if data was available from the ESTB for at least 4 satellites in view. Otherwise the GPS model broadcast in the ephemeris message was applied.

Integrity was computed in meters for the HPL and VPL as defined in the MOPS Do229A *[4]*, based on the variances of the fast corrections, ionospheric model, receiver measurements (modelled for a beta Class-3) and tropospheric model (using Niell mapping functions).

In-flight

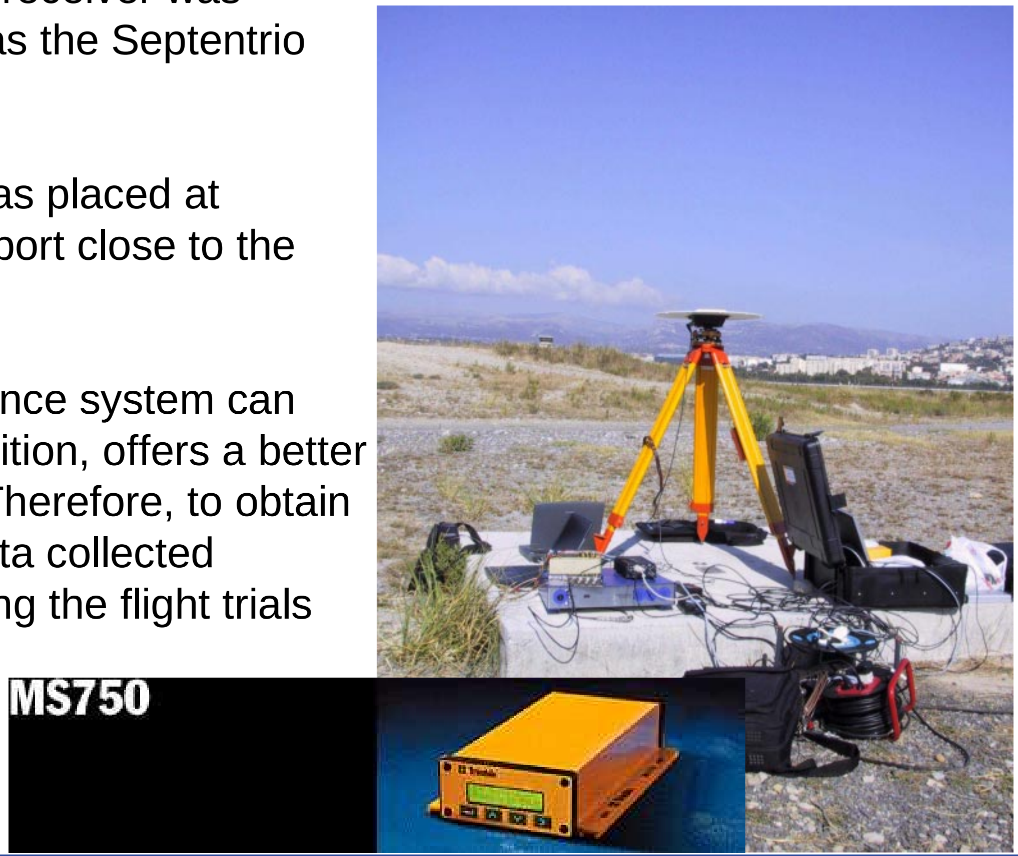
Trimble RTK
A truth reference

To asses the accuracy of the ESTB position in flight, a dual-frequency Trimble MS750 GPS-RTK rover and ground system were used as a truth reference.

On board the aircraft the Trimble receiver was connected to the same antenna as the Septentrio receiver guiding the approach.

The ground reference receiver was placed at surveyed location on the Nice airport close to the Runway04L.

Even if the Trimble MS750 reference system can provide a real-time reference position, offers a better accuracy after post-processing. Therefore, to obtain accuracy within the 1cm level, data collected on ground and in the aircraft during the flight trials are post-processed afterwards.



A second truth reference system was based on a set of Novatel Millenium OEM-3 receivers. One receiver was integrated inside the Cessna Citation II using the same antenna as Trimble and Septentrio, while the other receiver collected data on a surveyed point on the airfield next to the runway.

The second reference point was surveyed with kind support from the French REGAL GPS permanent network.

The two sets of carrier phase data, aircraft and ground, were processed using Commercial Software based on phase processing techniques (GeoGenius from Spectra Precision Terrasat) to generate a second truth reference

This second truth reference allows further analysis and comparison for the validation of the results.

In-flight

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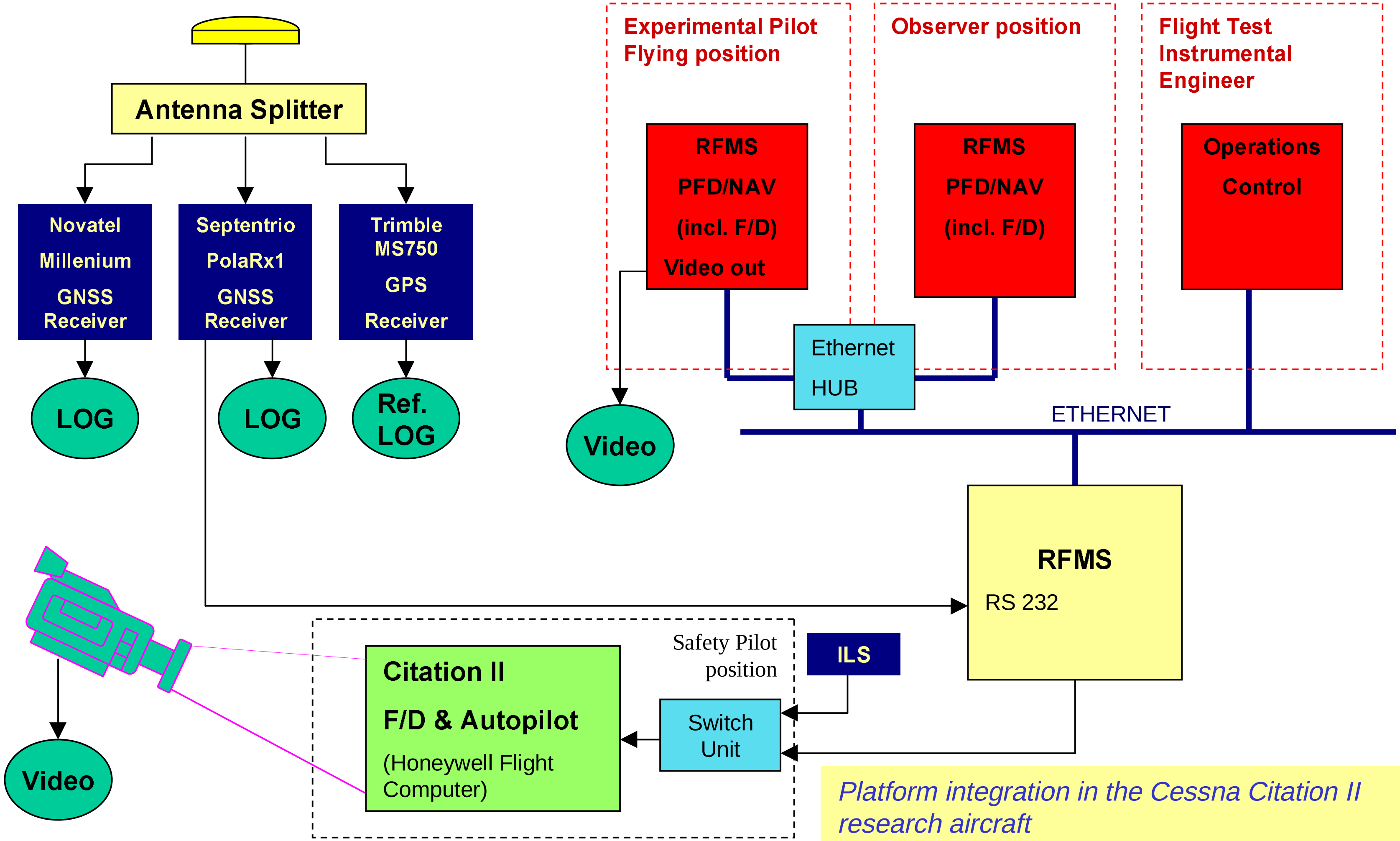

Platform integration in the Cessna Citation II research aircraft

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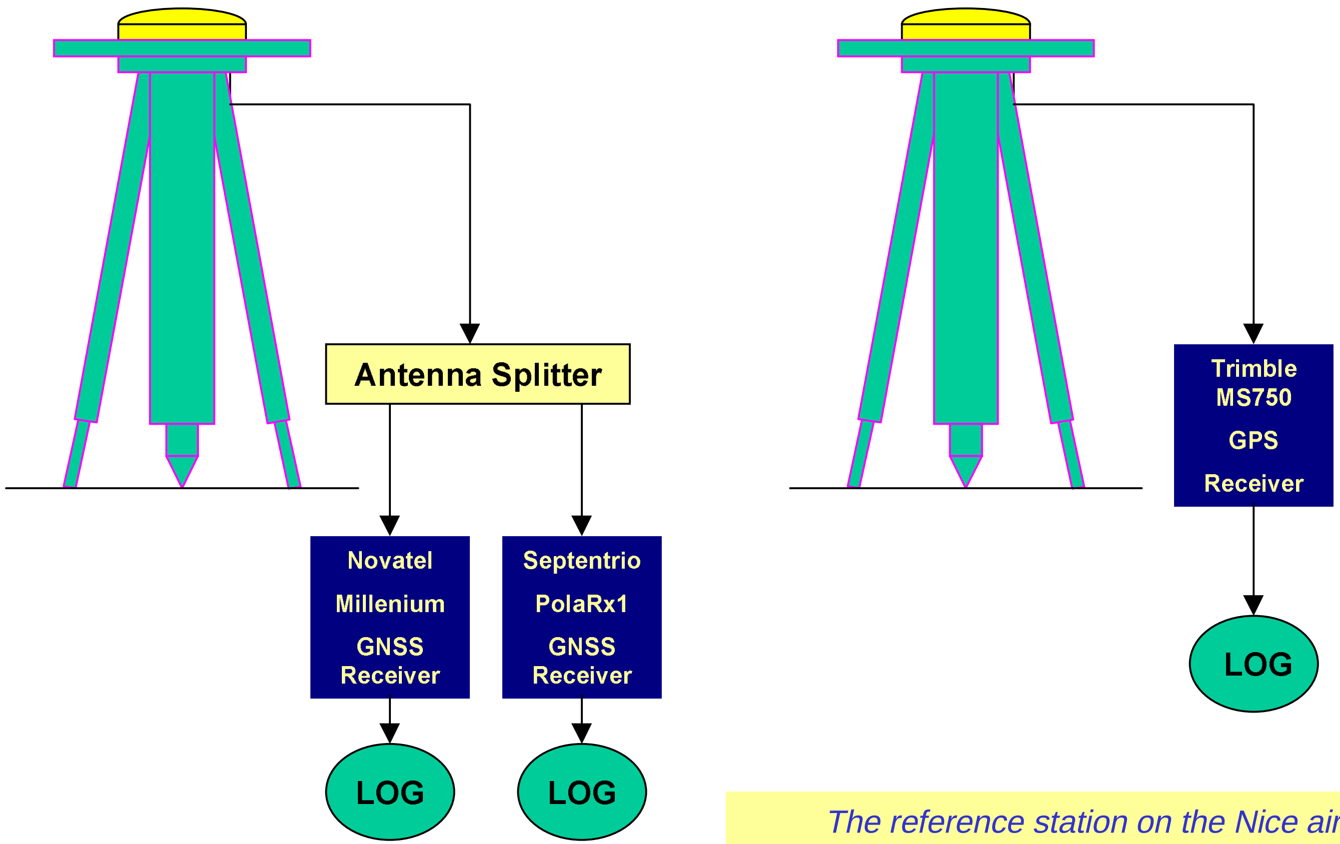


The reference station on the Nice airport

The configuration of the aircraft for the flight test aircraft is shown on the previous page *[pag. 19]*.

Septentrio provided a special version of their PolaRx-1 firmware able to provide in real-time with a required update rate of 10Hz, ESTB-positioning and integrity data to the Cessna Citation 's RFMS.

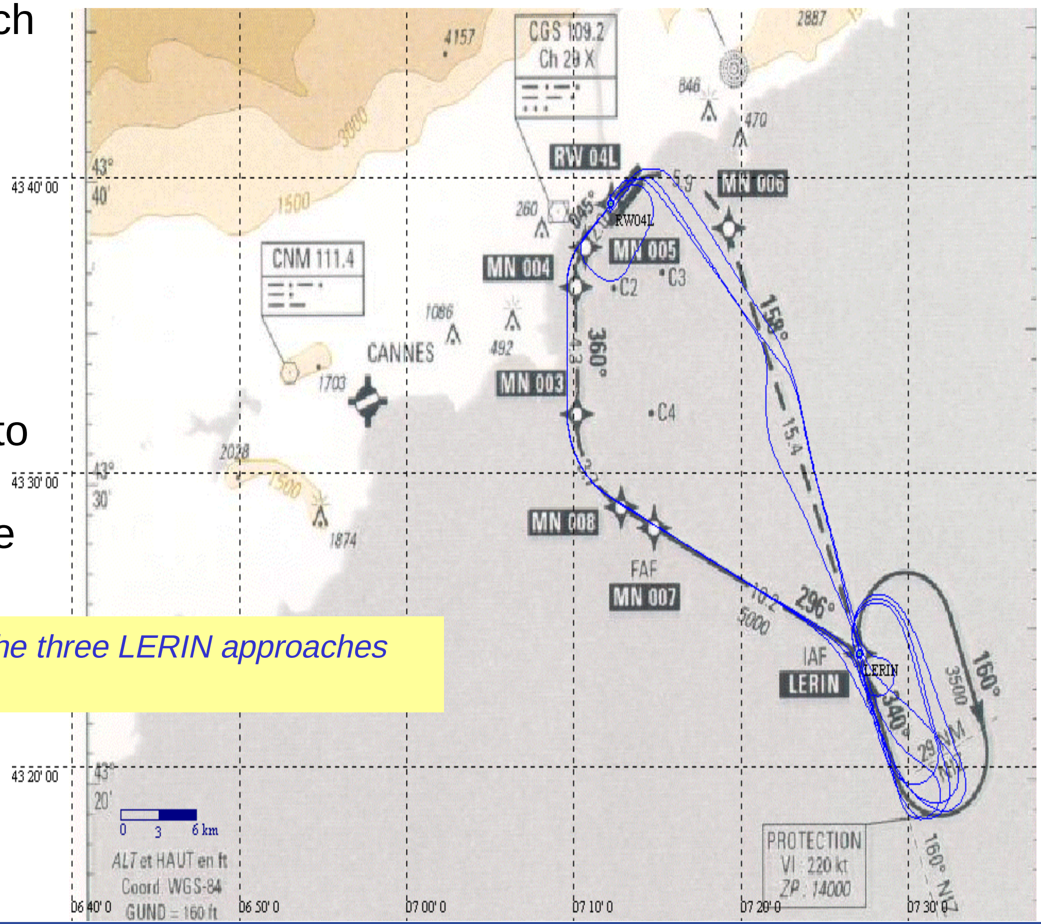
The curved procedure was coded in the RFMS. The resulting guidance information was presented on the research flight guidance display from the Removable Experimental Flight Deck. *[pag. 14]*

Integrity information of the ESTB is provided to the pilot by messaging when the GNSS-1 HPL (Horizontal Protection Level) is exceeding a predefined HAL (Horizontal Alert Limit) or when VPL (Vertical Protection Level) is exceeding the predefined VAL (Vertical Alert Limit).

In-flight

The EGNOS capability to provide aircraft guidance was investigated in two different ways at the airport of Nice: Firstly, by applying the ESTB positional and integrity data to support flying curved approach procedures, and secondly by providing ILS look-alike ESTB guidance to fly straight-in approaches.

The curved approaches from waypoints DRAMO *[pag. 9]* and LERIN *[see below]* were coded into the Citation's RFMS. A total of six approaches were flown, three from each waypoint.



The ground track of the three LERIN approaches flown to NICE airport

The ILS Cat-I is today the standard approach procedure to the airport of Nice under low-visibility conditions. This procedure is approaching the Runway04L straight over the peninsula of Antibes.

For flying the ILS-like approaches with GNSS-1 guidance, the RFMS was modified in order to interface with the Honeywell SPZ-500 Flight Computer.

ESTB positional data was fed into the route planner of the RFMS which translated this data into ILS localiser and glide-slope deviations. By means of a switch unit *[pag. 19]* this data could be selected instead of the ordinary ILS guidance to interface with the Cessna Citation's Honeywell Flight Computer, which in turn generates the Flight Director or auto-pilot guidance.

With this configuration, two series of three F/D guided approaches and auto-pilot guided approaches were flown.

Post-flight

During the flights data were collected on ground and on the aircraft to be analysed and post-processed afterwards:

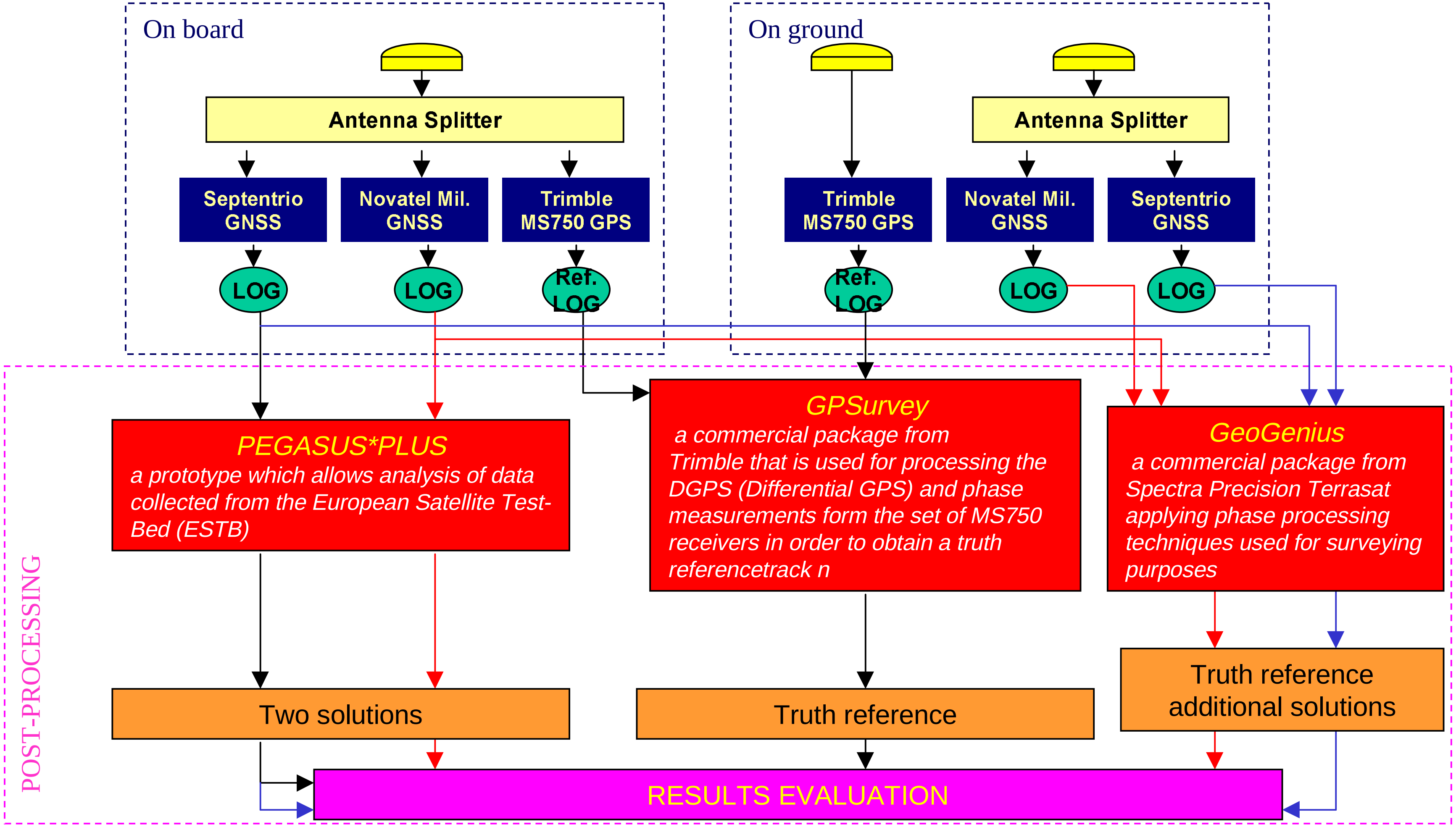
> On the ground:
- Septentrio PolaRx1 receiver output ESTB time, position and integrity data at 10Hz rate
- Novatel Millenium receiver output ESTB time, position data at 1Hz
- Trimble MS750 receiver output GPS position at 1Hz rate

> On the aircraft:
- Septentrio PolaRx1 receiver output ESTB time, position and integrity data at 10Hz rate
- Trimble MS750 receiver output GPS position at 1Hz rate
- Novatel Millenium receiver output ESTB time, position data at 1Hz

The objective of the data analysis is to determine the performance of the ESTB and the guidance derived during both manually and auto-pilot flown approaches.

Post-flight

A structured manner of Data Processing was established as shown below for results evaluation



Post-flight

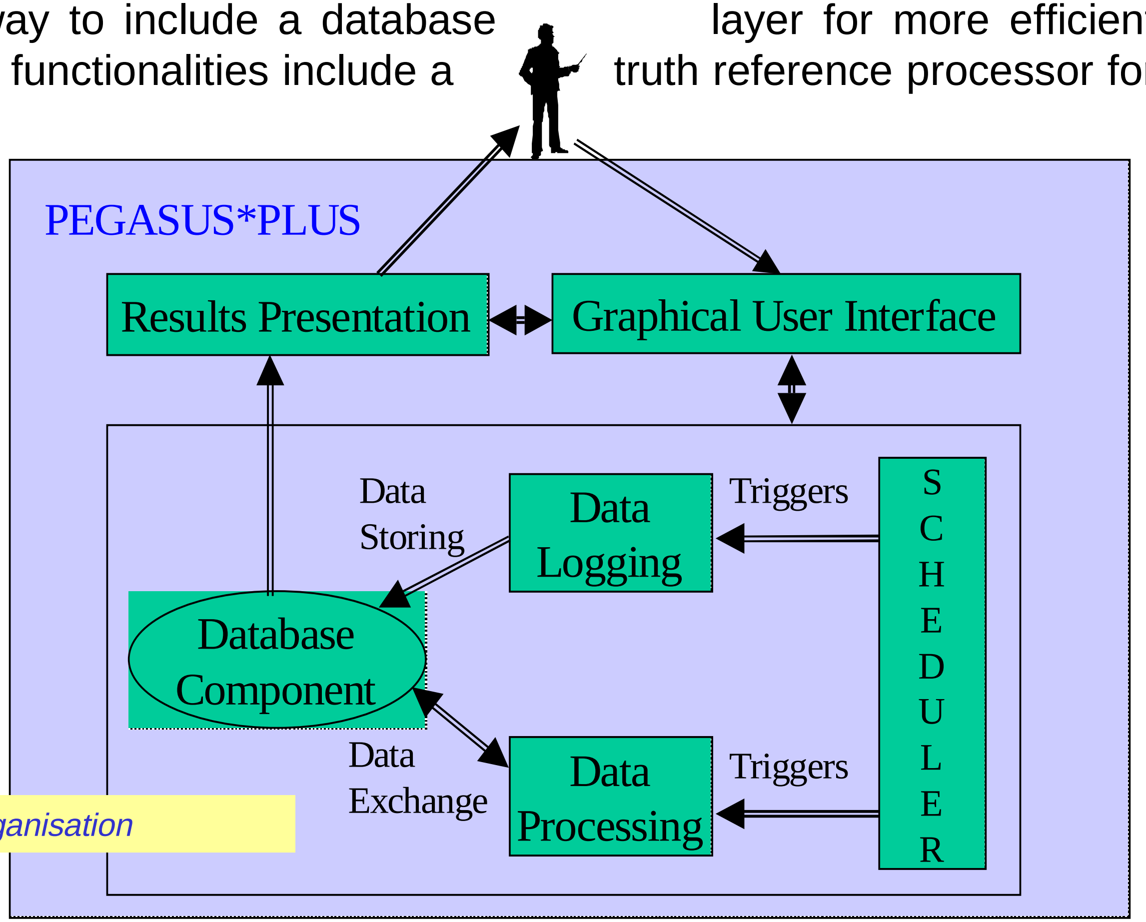
GOV Working Group, chaired by EUROCONTROL, is working towards a harmonised way of data processing and analysis of the SBAS measurements. For this purpose EUROCONTROL is developing the necessary tools.

PEGASUS*PLUS is a software prototype able to process data collected in-flight and on the ground with the European Satellite Test-Bed (ESTB).The PEGASUS*PLUS environment integrates five major software components.

- The CONVERTOR translates receiver-native GNSS data into a generic format
- The PLAUSIBILITY CHECK Program checks the output of the convertor and uses user-defined plausibility rules to detect any anomalies in the data set.
- The WinGPSALL program uses the output of the CONVERTOR to determine a GNSS navigation solution
- The ALGORITHMS use the output of the CONVERTOR and the WinGPSALL to analyse the satellite constellation, to determine predictive integrity monitoring qualifiers and to perform integrity monitoring using Receiver Autonomous Integrity Monitoring (RAIM) or Aircraft Autonomous Integrity Monitoring (AAIM) algorithms.
- The M-FILE RUNNER gives the possibility to the user to run a set of Matlab tools able to display results in different formats

Post-flight

The PEGASUS*PLUS environment facilitates the scheduling of tasks. Furthermore, developments are underway to include a database layer for more efficient storage of data. Additional functionalities include a truth reference processor for use with flight trial data.

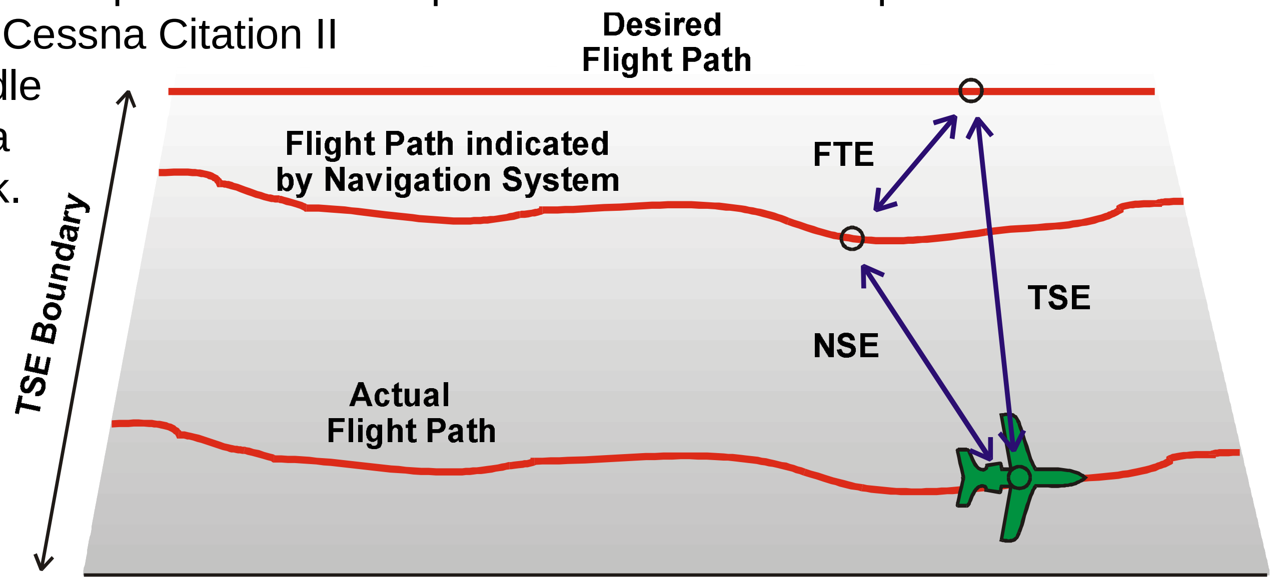


*PEGASUS*PLUS Organisation*

Post-flight

The ESTB NSE (Navigation System Error) performance is assessed, together with the FTE (Flight Technical Error) for both the F/D guidance with the man-in-the-loop as the auto-pilot guidance in case of the straight-in ILS look-alike approaches.

For the curved approach procedures comparison with the auto-pilot FTE is not feasible, because the Cessna Citation II auto-pilot cannot handle deviations in case of a curved approach track.



The NSE is the difference between the actual position of an aircraft and its computed position.
The difference between the required flight path and the displayed position of the aircraft is called Flight Technical Error FTE and contains aircraft dynamics, turbulence effects, man-machine-interface problems, pilot errors, etc.
The vector sum of the NSE and the FTE is the Total System Error.

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The flight test data were processed in line with the diagram on page 26. The next pages show the results of the trials following the format shown below.

Data have been analysed based on various assumptions and criteria in order to deal with reference data outages, ESTB SIS outages, receiver failures, etc.

Approach			NSE(m)=Δ (Trimble MS750 position output, Septentrio PEGASUS*PLUS position ouput)				FTE(m)=Δ (Septentrio sampled by RFMS, desired programmed RFMS path)
	Availability of valid samples (%)	Number of samples	HPE (95%)	VPE (95%)	HPL (95%)	VPL (95%)	FTE Lateral (mean/standard deviation)
	Criteria: corresponding match between reference and Septentrio, and valid position label	Number of samples corresponding to procedure length (IAF to THR RW04L on basis of reference track	Criteria: used sample values when the PEGASUS*PLUS output position and XPL are labeled as valid				FTE is the difference between Septentrio position sampled by RFMS and desired position in RFMS calculated at 10Hz. Only computed during approach Criteria: Start= FAF (First Approach Fix) End=THR RW04 (Threshold Runway 04)

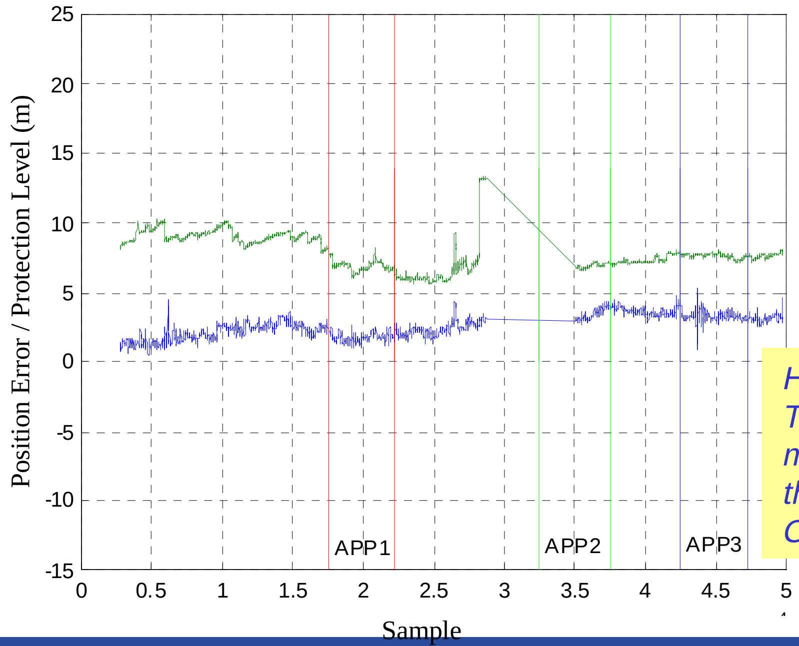
XPL (HPL/VPL) Protection Levels: is the radius of a circle in the Horizontal/Vertical plane (the plane tangent to the WGS84 ellipsoid), with the centre being at the true aircraft position, which describes the region which is assured to contain the indicated Horizontal/Vertical position displayed by the Navigation System. It is the Horizontal/Vertical region for which the missed alert requirements can be met, acting as an upper bound for the Horizontal/Vertical SE.

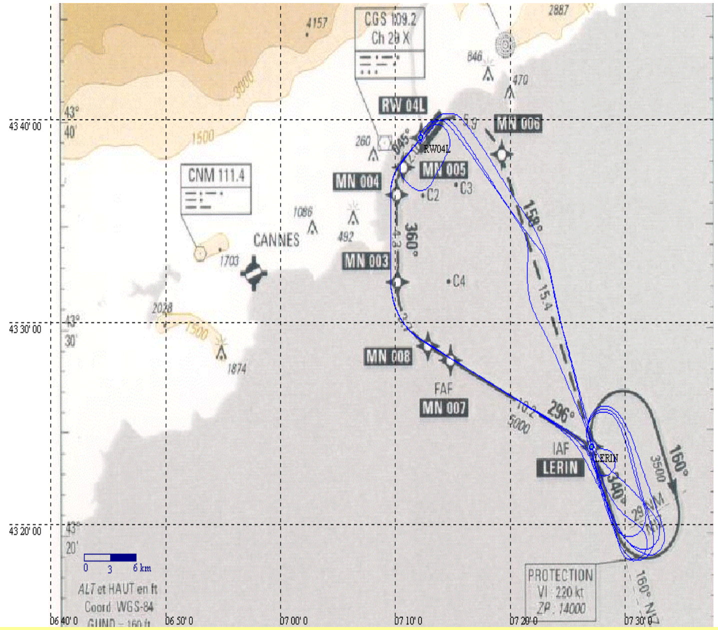
Post-flight

LERIN: Challenging VOR/DME guidance

A series of three curved approaches were flown starting at waypoint LERIN.

			NSE(m)				FTE(m)
1	100	473	2.3	6.6	7.7	17.3	2.6/25.9
2	49.6	495	4.1	2.6	7.2	15.1	18.7/18.8
3	100	477	3.9	3.1	7.9	17.0	18.6/15.9





Horizontal Position Error and Horizontal Protection Level
The Protection Level overbounds the Position Error with sufficient margin, and the Position Error didn 't exceed the PL during any of the three approaches.
Outage of data during the second approach.

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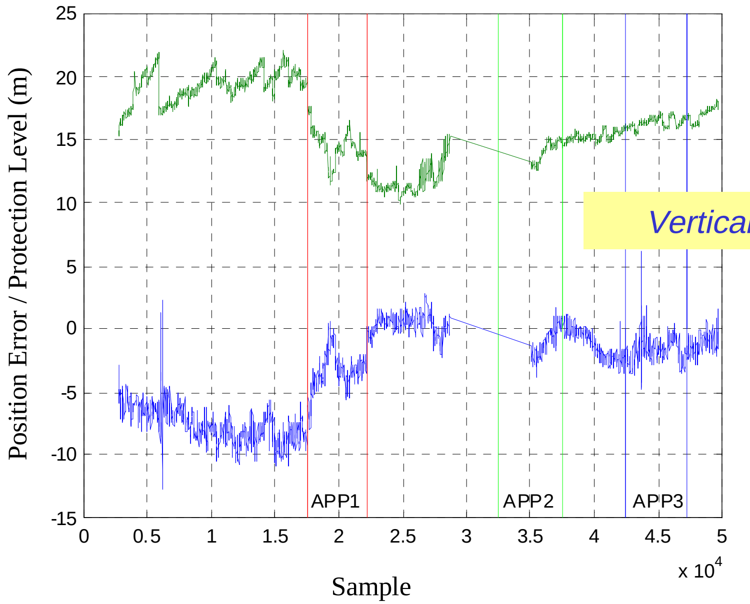
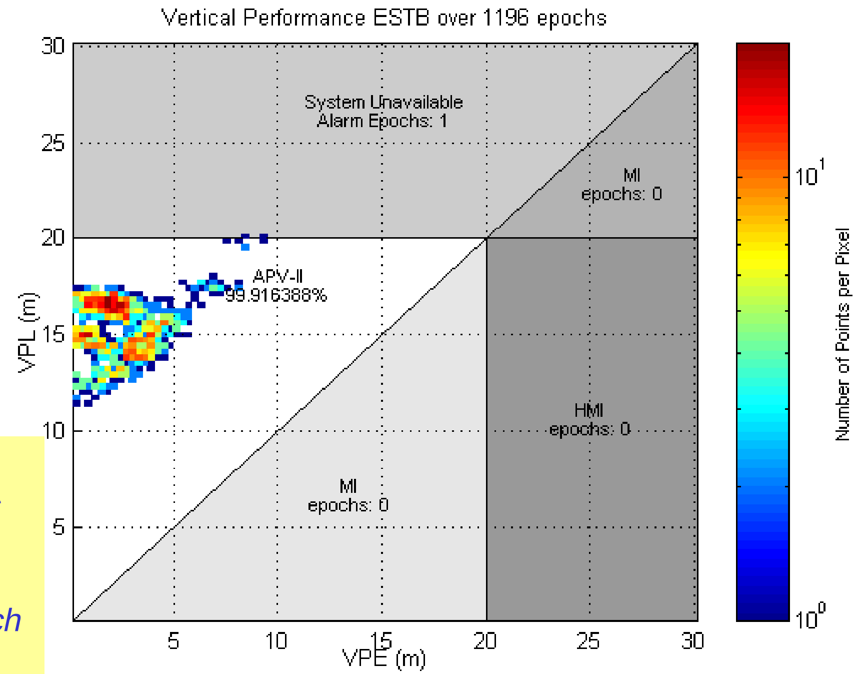
Post-flight



Vertical Position Error and Vertical Protection Level



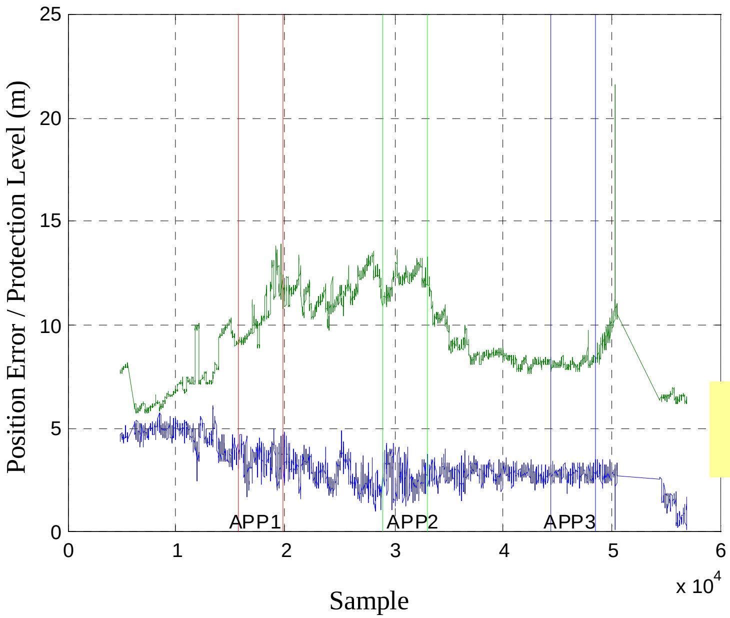
Stanford plot showing the VPL against VPE from the dataset including the three LERIN curved approaches datasets merged.
The plot shows performance in terms of accuracy, availability and integrity considering the APV-II approach procedures Alarm limits

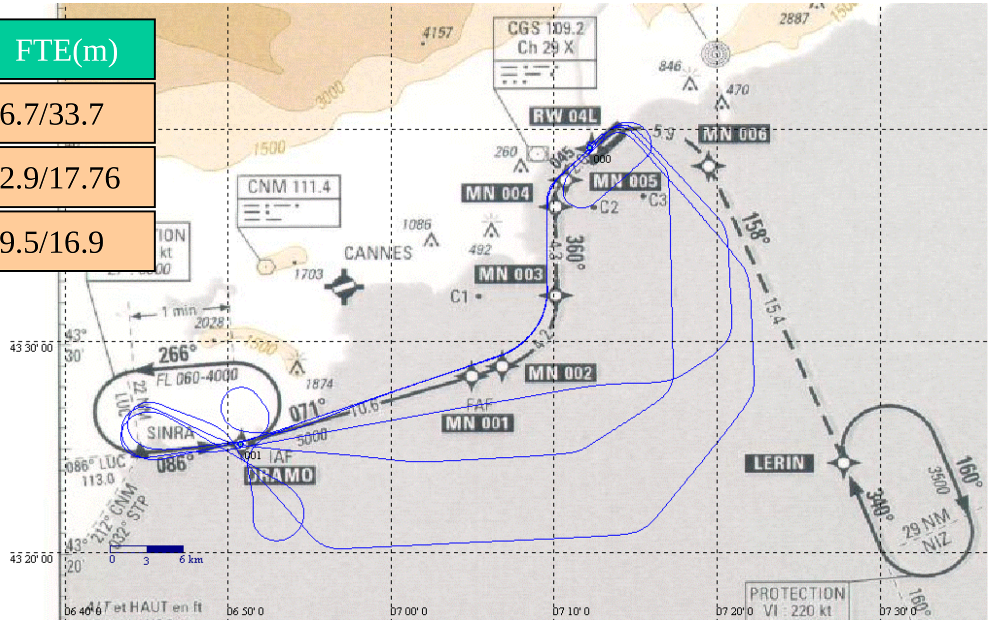
Post-flight

DRAMO: Rounding Cap d ’Antibes smoothly

A second series of three curved approaches were flown from waypoint DRAMO.

			NSE(m)				FTE(m)
1	100	419	4.4	4.2	13	15.2	6.7/33.7
2	100	423	3.8	5.2	13.1	19.5	2.9/17.76
3	100	419	3.2	2.3	8.5	15.6	9.5/16.9





Horizontal Position Error and Horizontal Protection Level for all DRAMO approaches

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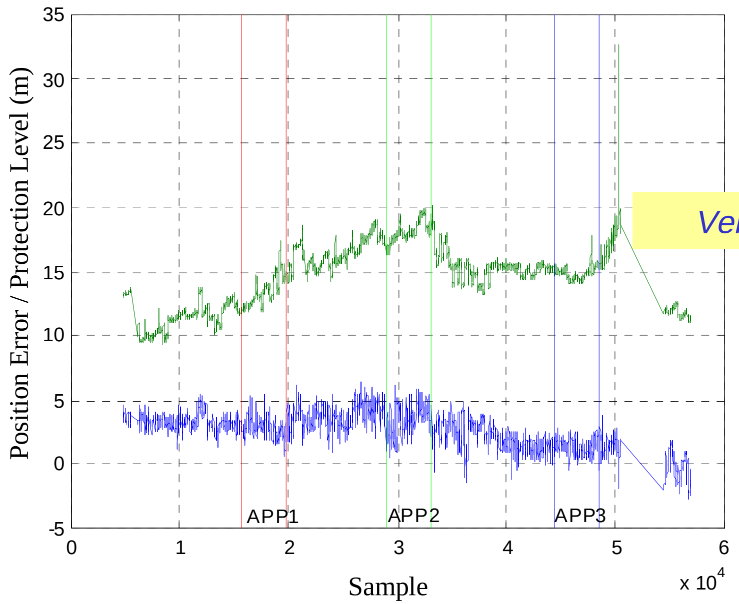
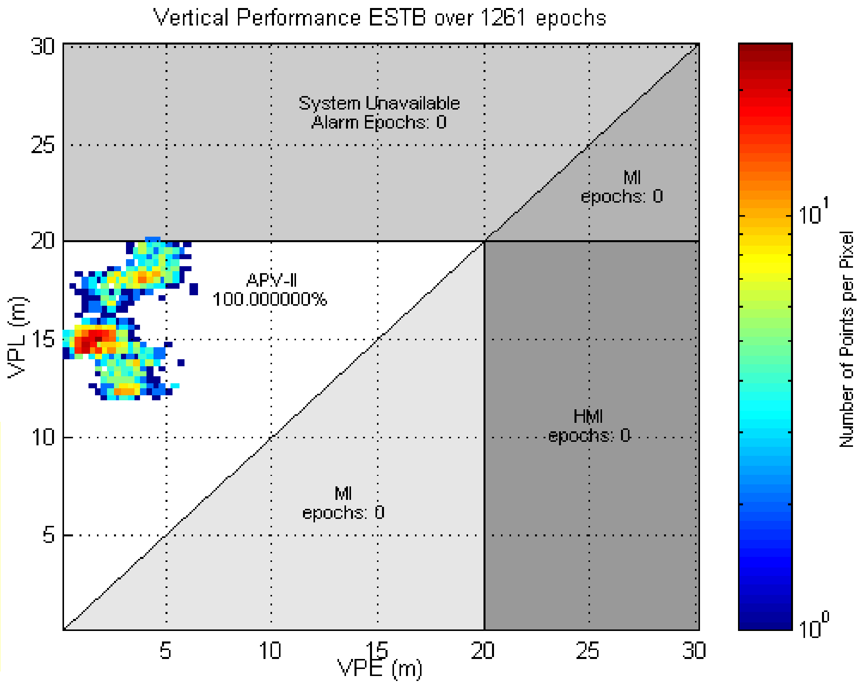


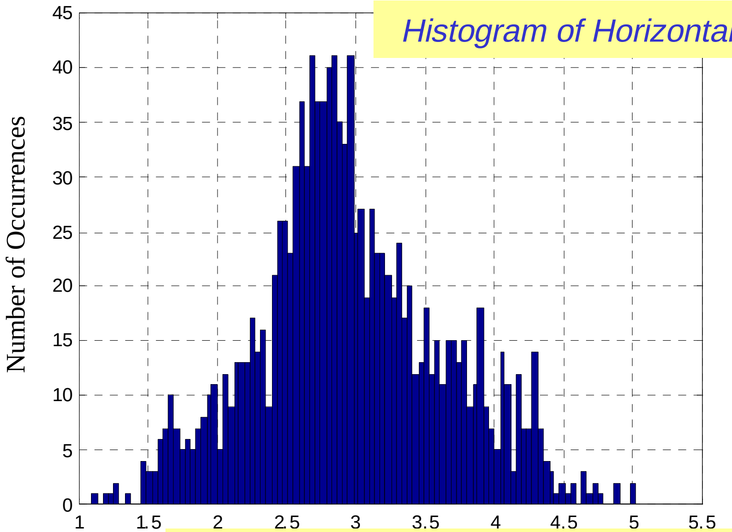
Vertical Position Error and Vertical Protection Level



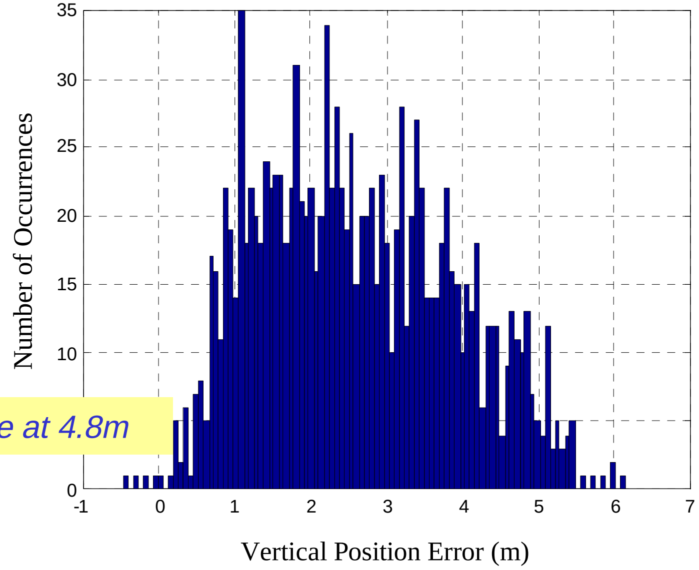
Stanford plot showing the VPL against VPE from the dataset including the three DRAMO curved approaches datasets merged.
The plot shows performance in terms of accuracy, availability and integrity considering the APV-II approach procedures Alarm limits

Post-flight

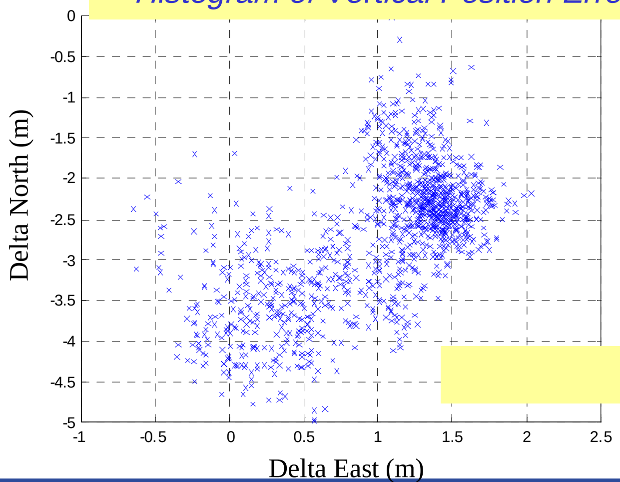
DRAMO: Rounding Cap d 'Antibes smoothly



Histogram of Horizontal Position Error - 95% percentile at 4.2m



Histogram of Vertical Position Error - 95% percentile at 4.8m



Horizontal Position Error distribution

Results obtained from the dataset including the three DRAMO curved approaches datasets merged.

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DRAMO: Rounding Cap d 'Antibes smoothly

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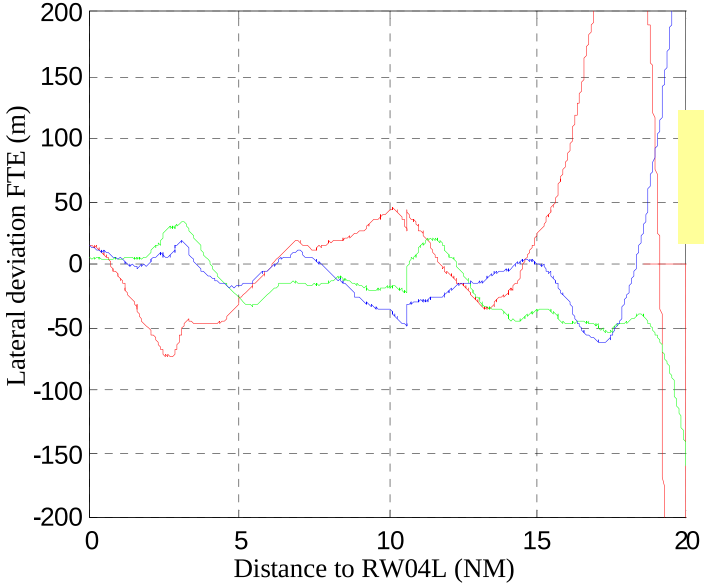
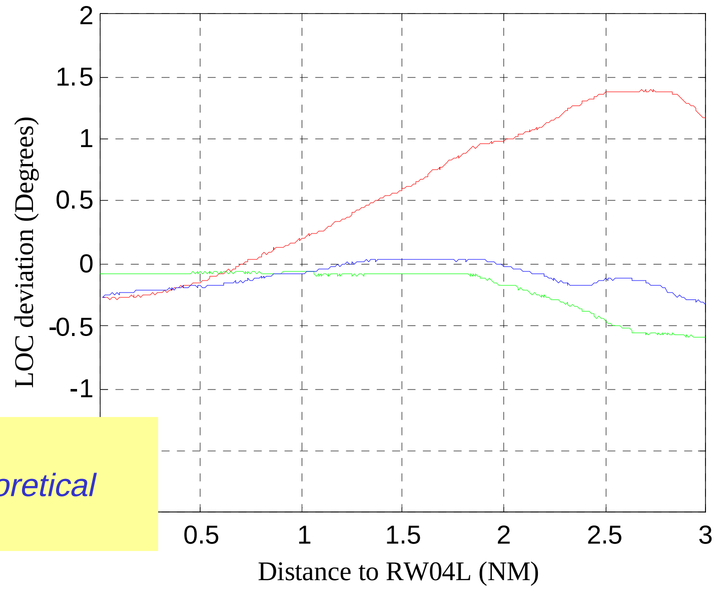


Lateral FTE along the approach (IAF to RW04L THR) given in meters.
The distance to the RW04L is in the x-axis

Red = First approach   Green = second approach
Blue = third approach

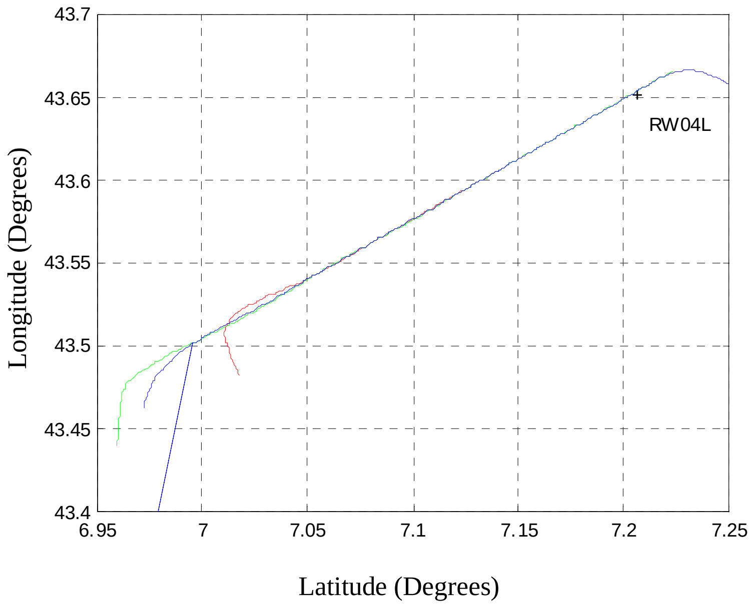


Lateral FTE of the last 3NM of the approach
The deviation is calculated in degrees from the theoretical localizer signal

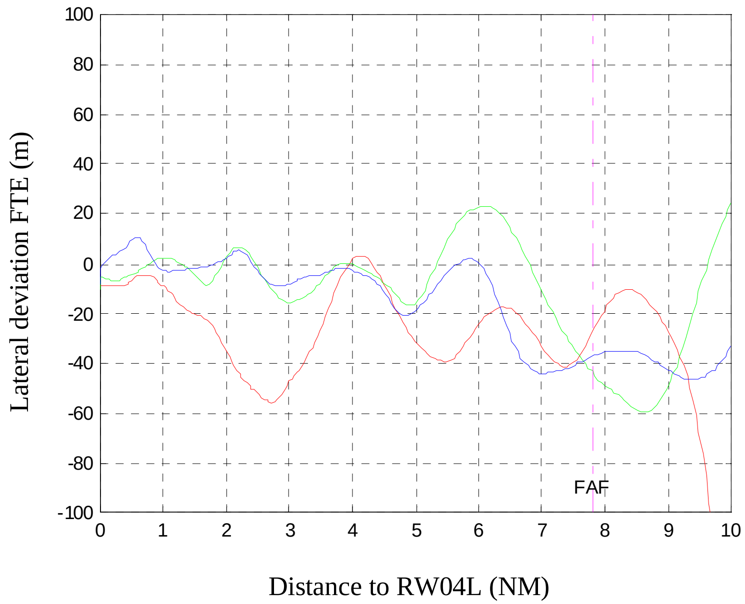
Post-flight

ILS-like F/D: GNSS-1 appears like ILS guidance

The ILS approach was also flown manually in a series of three approaches with the Flight/Director.

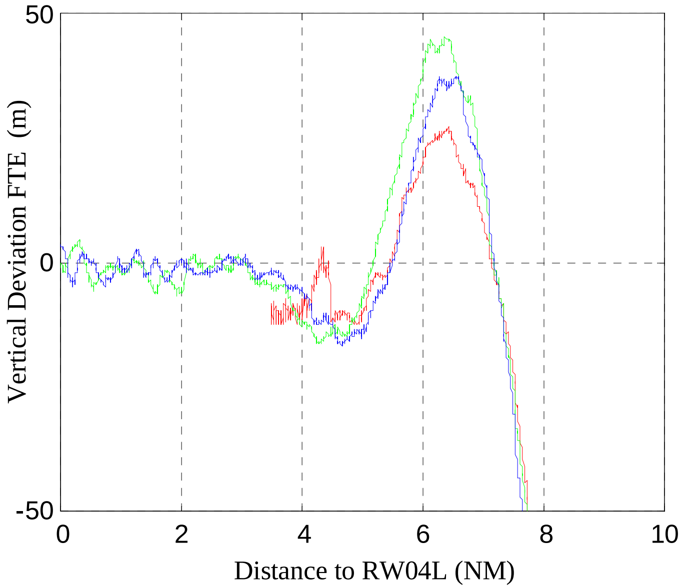


Red = First approach Green = second approach
Blue = third approach

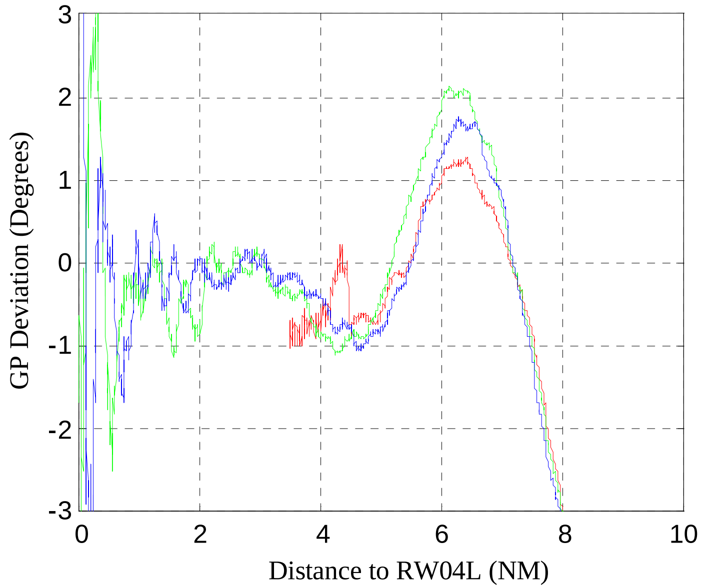


Lateral FTE along the approach (IAF to RW04L THR) given in meters.
The distance to the RW04L is in the x-axis

The ILS-like straight in approaches give the possibility to calculate the FTE in the vertical guidance.



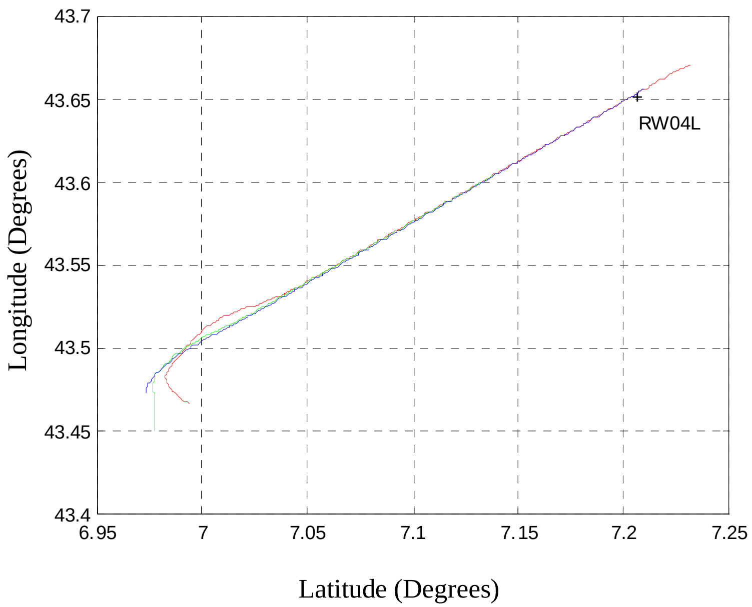
Vertical FTE along the approach (IAF to RW04L THR) given in meters.
The distance to the RW04L is in the x-axis



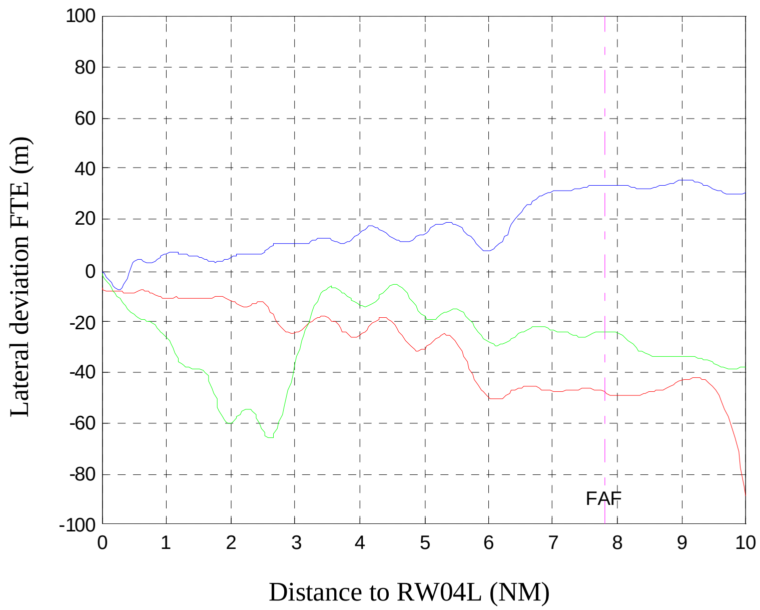
Vertical FTE of the last 10NM of the approach
The deviation is calculated in degrees from GP signal

Red = First approach   Green = second approach
Blue = third approach

Finally a series of three ILS approaches with the Citation's Auto-Pilot were flown.



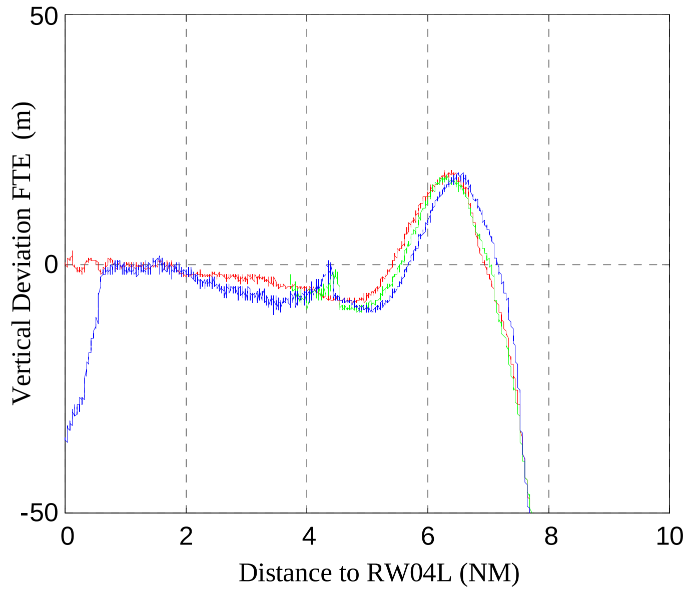
Red = First approach Green = second approach
Blue = third approach



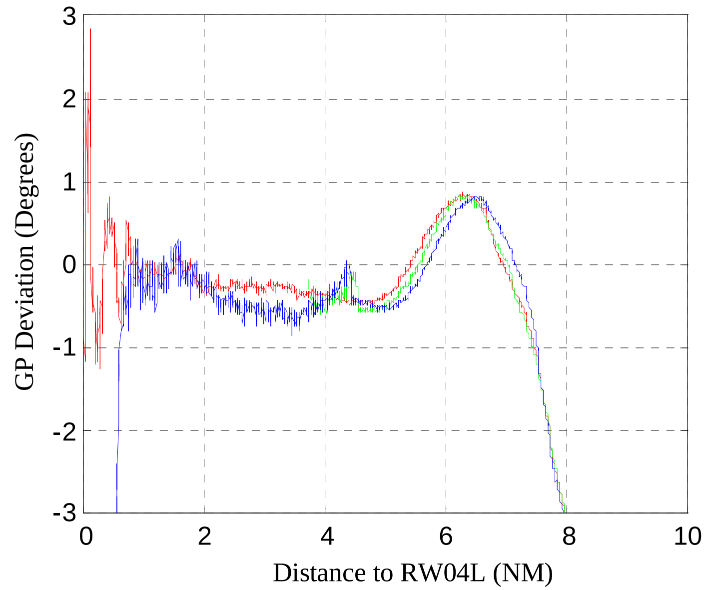
Lateral FTE along the approach (IAF to RW04L THR) given in meters.
The distance to the RW04L is in the x-axis

Post-flight

ILS-like A/P:
ILS-like with GNSS-1 and authomatically



Vertical FTE along the approach (IAF to RW04L THR) given in meters.
The distance to the RW04L is in the x-axis



Vertical FTE of the last 10NM of the approach
The deviation is calculated in degrees from GP signal

Red = First approach Green = second approach
Blue = third approach

Post-flight

After the flights, the pilots provided a report on their experiences. Their experience in general was quite positive;

« The flight director guidance from the RFMS used for the curved approaches was very smooth and provided for accurate tracking.

The Septentrio receiver in general gave stable output of HPL and VPL values and no jumps in position were experienced. Under high dynamics the receiver experienced brief interruptions during which control was transferred to the safety pilot monitoring the ILS guidance.

Basically it was easy to fly the curved approaches using the guidance from the ESTB»

Post-flight

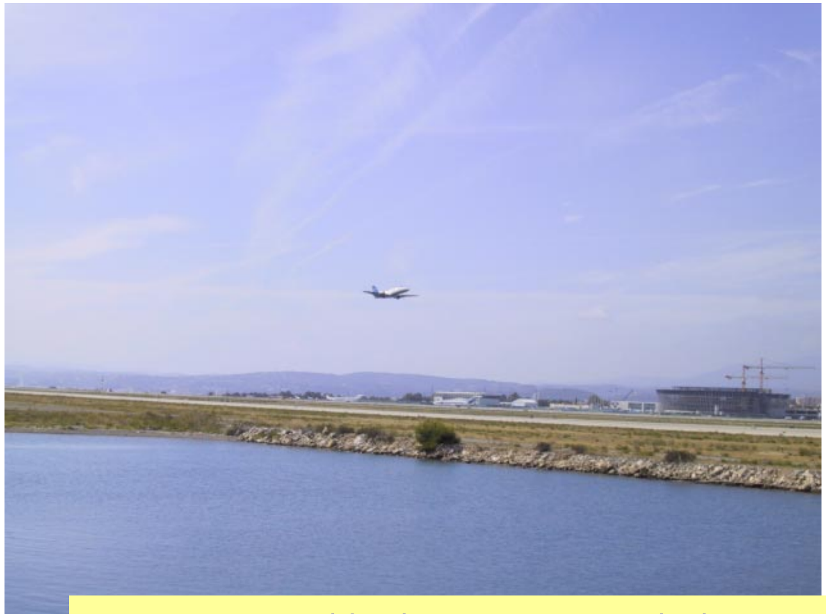
« We flew the curved approach from LERIN using the flight director based on the ESTB. The intermediate approach track of 296 was easy to intercept and maintain. The level altitude was easy to maintain as well with the guidance and the interception of the GNSS glide slope was smooth and clear. Turning to the right at MN008, with speed 180Kts, was easy, an the bank angle was well controllable with the speed reduced to 160Kts.

At MN003 the flaps were selected. Afterwards, during the straightdescent between this waypoint and the next MN004, the speed was reduced to 140Kts. The final right turn at MN004 aligning the RW04L was smooth and easy to control even with a slight tail wind (180/7), with bank angles between 10 and 20 degrees »

For the DRAMO approaches the same smoothbehaviour was observed by the pilots.

Post-flight

« We flown the first three straight-in approaches manually and the last three on the Auto-Pilot. During all the six approaches, localiser interception was a little bit too slow with very small bank angles. Also, a number of times a slight oscillation in the bank angle was observed while tracking the Localiser/Glide-Slope on the autopilot.But in general we were very impressed with the guidance from the ESTB system.»



A go-around for the NLR Cessna Citation II

The flight simulations in Istres in the south of France and the approach trials to Nice have confirmed that EGNOS is a promising navigation aid to support RNAV approach operations and more particularly curved approaches. The trials that were reported on in this paper were primarily focussed on obtaining first experiences and on demonstrating potential capabilities.

Further work will need to have a larger focus on operational implementation. To this aim the GNSS-1 Operational Validation Working Group is currently developing an operational concept document describing how EGNOS will be used in Europe in the future. Furthermore support is provided to the work going on in the ICAO Obstacle Clearance Panel. Further trials planned in the near future will support this work and in addition will focus on the development of EGNOS-based approach operations in the Member States.

Follow the developments on the GOV website:
http://www.eurocontrol.fr/projects/sbas

For information on EGNOS and the ESTB check the ESA web-site:
http://www.esa.int/navigation

EUROCONTROL

Acknowledgements

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NavConvention

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Under contract to EUROCONTROL different organisations have contributed to the work and results described:

- The Centre d'Essais en Vol in Istres (France) performed the simulations of the Nice approach
- NLR in the Netherlands performed the flight trials with their Cessna Citation II research aircraft
- Septentrio in Belgium provided a special version of their PolaRx-1 firmware and excellent technical support during the flight trials
- The Technical University of Braunschweig in Germany supported Septentrio

Finally, special thanks to the following people and organisations:

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- STNA that provided much support in the setting-up of the flight trial
- Claude Pambrun and Eric Calais from REGAL Network *(Reseau GPS Permanent dans les Alpes)* kindly helped during the surveying of the ground antennas at Nice airport
- ESA, and in particular the ESTB team, that provided special continuous monitoring of the ESTB during the activity and offered their evening and night hours for the success of the flights
- last but not least our colleagues in the Eurocontrol Experimental Centre, Hervé Bechtel and Jos Follon, who used the Nice activity to develop a great video, and Sebastien, David and Ivan from our GNSS tools development team who together with the Technical University of Braunschweig made sure that all the necessary tools for the data processing were available on time.

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