EUROCONTROL

GNSS Multi-constellation Solutions for State Aircraft

Flight Test Campaign Specifications

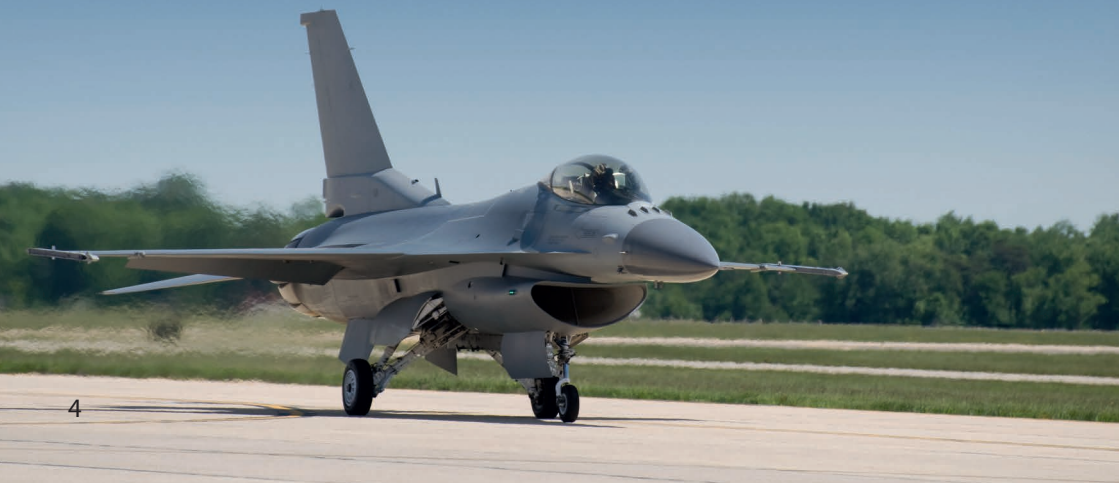
Executive Summary

Table of contents

1. BACKGROUND

Today, most modern European military aircraft are fitted with Global Positioning System (GPS) / Precise Positioning Service (PPS) receivers, operating with restricted satellite signals. In the effort to enhance interoperability, rationalise military avionics and reduce costs, a similar approach to the one used by civil aircraft operators could be adopted in order to support common aeronautical navigation requirements, based on dual constellation configurations and the combined use of GPS PPS and Galileo Public Regulated Service (PRS) signals.

The military community expects that the use of restricted signals by State aircraft should be capable of providing an equivalent level of performance to their civil counterparts.



2. OBJECTIVE

The study was conducted in the first half of 2016[1] with a view to describing the operational context and system options for the integration of State aircraft[2] into a Single European Sky ATM Research (SESAR) operational environment by:

- integrating results from a previous military study on GNSS (Global Navigation Satellite System): Multi-constellation Precise Signals for State Aircraft;

- providing a detailed and comprehensive State aircraft Flight Trial Campaign (FTC) specification, when using GNSS restricted signals for navigation in a PBN (Performance Based Navigation) application context and in a mixed-mode environment.

The outcome of this study led to a technical contribution to SESAR Project 9.27 (Multi-constellation GNSS Airborne Navigation Systems).

The flight trial campaign was aimed at the subsequent potential integration and execution of multi-constellation GNSS airborne navigation systems in the SESAR 2020 Work Programme – Very Large Scale Demonstrations or any other relevant validation/demonstration initiatives.

1- EUROCONTROL study commissioned to NLR – Netherlands Aerospace Centre

2- The flight trial campaign

3. THE FLIGHT TRIAL CAMPAIGN: A DESCRIPTION

In the FTC, these are the most prominent specifications:

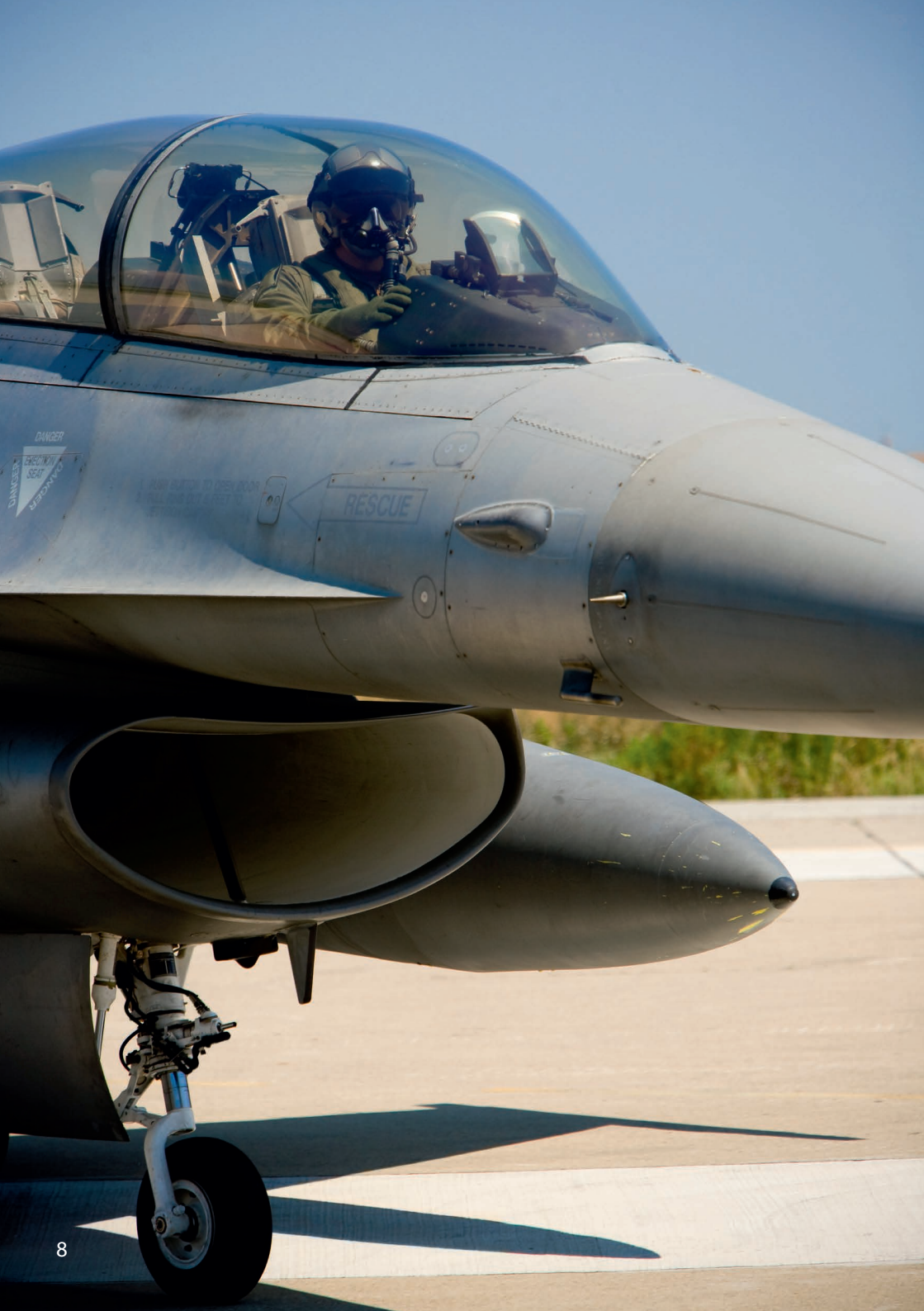
- performance assessment on State aircraft operating in a PBN environment on the basis of the use of GNSS restricted signals;
- an FTC context-definition, based on PBN environment dictated by the levels of navigation performance described in ICAO Doc 9613 (PBN Manual);
- State aircraft equipage scenarios delineated in a previous military GNSS study;
- required instrumentation and resources (e.g. multi-constellation GNSS receiver relying on restricted signals), State aircraft modifications and associated certification materials;
- flight trial scenarios (i.e. 'no cost constraint' solution, 'best value for money' solution, 'minimum cost' solution) and inherent cost assessments for both transport-type and fighter military aircraft.

3.1. FTC context definition

The definition of the flight trial campaign is underpinned by a set of operational and technical provisions to demonstrate performance compliance/equivalence of State aircraft in a PBN environment:

- the flight profiles should be sustained by PBN-based routes and procedures and carried out in non-segregated airspace;
- the airport/aerodrome and terminal area environment should be able to provide PBN airspace structures and, in parallel, accommodate flight trials[3];
- flight tests should be carried out using a serviceable GALILEO constellation together with GPS constellation when upgraded to M-code;
- State aircraft considered more suitable for the FTC are transport-type and fighter aircraft, due to the level of interaction with the overall ATM system;
- the use of a Multi-Constellation Receiver (MCR) [or independent receivers until the MCR configuration has been industrialised] for processing restricted signals will ensure the same levels of performance that are derived from ICAO SARPs and civil standards. It should also be compliant with the relevant military standards on GNSS restricted signals;
- the MCR equipment must be capable of supporting, at least, RNAV1 and RNP1 for en-route and TMAs and RNP APCH for the approach and landing phases of flight;
- the preferred configuration for State aircraft multi-constellation receivers should comprise Galileo PRS/OS + GPS SPS/PPS + SBAS (L1/L5). However, the applicability of such MCR in the FTC depends on its availability (e.g. prototype);
- suitable navigation fall-back options in case of (intentionally) degraded MCR performance; conventional/alternative navigation procedures/ support should be in place.

3- Busy airports are expected to have PBN-based procedures in place in a shorter timeframe but are less flexible for accommodating flight trials, which means that a smaller airport is a feasible alternative.


DANGER
EJECTION SEAT
DANGER
RESCUE

3.2. FTC scenarios description

The definition of the scenarios for the flight trial campaign was determined by the levels of PBN navigation performance to be tested (applications and functionalities) as well as by the system configurations that are needed for those performance levels. For that purpose, the focus is on peacetime operations in a GAT/SESAR trajectory management environment with these operational profiles defined as baseline:

- en-route
  - RNAV1/RNP1 requirements
- TMA
  - RNAV1/RNP1 STAR using Continuous Descent Operations (CDO)
  - i4D trajectory management using RTA
  - RNAV1/RNP1 SID
- approach and landing
  - RNP APCH relying on LNAV/VNAV and/or LPV.

As a result, the flight profiles that ensure both safety and consistency in using satellite restricted signals are derived from the best trade-off between cost and operational benefits.

3.3. FTC resources selection

The FTC needs a multitude of operational and technical arrangements for aircraft and non-aircraft-related resources in assessing the use of GNSS restricted signals by State aircraft in a PBN context. The table below reflects the type of resources that are deemed necessary in carrying out the exercise.

Table 1. Summary of the main resources identified for the FTC.

Resource	Description
Base of operation	A military Air Base should facilitate compliance with the required security measures (support to test aircraft and flight test activities)
NAVAID infrastructure	Space- and ground-based navigation infrastructure needs to be available (e.g. GPS and Galileo constellations)
Navigation data	The navigation database suppliers should comply with international standards (e.g. ED-76/Do-200A)
Flight mission profile	The flight mission profile will be used to feed the aircraft mission computer with navigation data to support PBN operations. The files should be verified using the flight simulator prior to each flight
Operating procedures	Pilot must adhere to AFM (FCOM) limitations or operating procedures required to operate under the required PBN specifications. Back-up procedures must be available.
Airspace requirements	Non-interrupted PBN operations. Non-segregated airspace. Low conflict with other traffic
ATC	The ATCOs should have completed training that covers basic PBN procedures, ATC-specific requirements and system training
Flight Planning	Provision of AIS and flight data. Submission of flight plan
Flight crew	CAT 1 or CAT 2 accredited test pilots. Trained to operate the MCR equipment. Trained for PBN operations (flight simulator may be used)

GNSS receiver crypto keys	Crypto keys issued by the appropriate regulatory body and/or national operator. Those crypto keys must be loaded into the GNSS and experimental MCR prior to the test flight
Test aircraft (examples)	Transport-type: Hercules C-130. Fighter: Lockheed F-16
MCR requirements	Compliant with TSOs, Mil-Std, and security requirements. GPS SPS+PPS / Galileo OS+PRS modes of operation, including pure PPS+PRS position solution. Additional provision of SBAS L1/ L5 and/or barometric capability to support APV operations. RAIM capability. Integrity alerts and vertical and horizontal protection levels
FMS requirements	Support GNSS receiver inputs according to ARINC 429 standards. Support MCR RAIM capabilities. Support PBN monitoring and alerting capability. ARINC 424 compliance. Integration with other sensors such as DADC and IRS/INS type equipment
On-board monitoring	A NSE monitoring and alerting capability (e.g. and alerting equipment RAIM or FDE algorithm) required plus a lateral navigation display indicator (e.g. CDI or (E)HSI) enabling the crew to monitor the FTE
Aircraft modification	Modification of test aircraft required and of temporary nature. Shall be approved by Part 21 and performed by Part 145 maintenance organisations
Reference position	Recording of independent GNSS reference data. Data analysis leading to parameters such as FTE and TSE
Flight Test Instrumentation suite	Navigation data and meta data acquired and recorded during flight tests.
Ground testing	Safety of Flight test (SOF) carried out prior to the start of the FTC (including EMC/EMI confidence check after approval by the relevant authorities). Continuity check and data integrity check of both the MCR installation and the FTI suite to be done
No Technical Objection and Permit to Fly	No Technical Objection (NTO) required. Issued by the Military Type Certificate Holders Organisation (MTCHO). Application of a Permit to Fly (PtF) from the national MAA

3.4. FTC cost assessment and planning

A set of three flight test campaign solutions have been defined, i.e. 'no cost constraints', 'best value for money' and 'minimum cost solution', which mainly differ in the number of flight hours and the number of PBN procedures executed. The outcome of the valuation process, which comprises the analysis of the FTC preparation, the test aircraft modification, the exercise execution, and the post flight data analysis and assessment, identifies the 'minimum cost solution' as being the least expensive solution and the one with the highest scientific relevance / cost ratio.

In terms of planning, the project is expected to last 12 to 14 months. This estimate is done on the basis of only one set of test equipment being available. The project schedule can be segmented in four phases:

- FTC preparation, including obtaining approval: 6 months
  - 4 months for the design and realisation
  - 1 month to obtain a NTO approval
  - 1 month to obtain a PtF
- FTC execution for the fighter test aircraft: 2-3 months
- FTC execution for the transport test aircraft: 2 months
- FTC post flight data analysis and reporting: 2-3 months

4. FINAL REMARKS

The outcome of this study offers a specification for an FTC that can be used when it has been decided to conduct a validation trial/demonstration for State aircraft's accommodation in PBN structures using GNSS restricted signals. It must be considered together with the results from a previous EUROCONTROL study[4] where the operational scenarios for the same purpose were delineated.

4- Commissioned to Rockwell Collins and FDC in 2011

LIST OF ACRONYMS

(E)HSI	(Electronic) Horizontal Situation Indicator
AFM	Airplane Flight Manual
APCH	Approach
APV	Approach Procedures with Vertical Guidance
CDI	Course Deviation Indicator
CDO	Continuous Descent Operations
DADC	Digital Air Data Computer
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
FCOM	Flight Crew Operating Manual
FDE	Fault Detection & Exclusion
FMS	Flight Management System
FTC	Flight Test Campaign
FTE	Flight Technical Error
FTI	Flight Test Instrumentation
GAT	General Air Traffic
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
i4D	Initial 4D
ICAO	International Civil Aviation Organisation
INS	Inertial Navigation System
IRS	Inertial Reference System
LNAV	Lateral Navigation
LPV	Localiser Performance with Vertical Guidance
MAA	Military Aviation Authority
MCR	Multi-Constellation Receiver
Mil-Std	Military Standard
MTCHO	Military Type Certificate Holders Organisation

NSE	Navigation System Error
NTO	No Technical Objection
PBN	Performance-Based Navigation
PPS	Precise Positioning Service
PRS	Public Regulated Service
PtF	Permit to Fly
RAIM	Receiver autonomous integrity monitoring
RNAV	Area Navigation
RNP	Required Navigation Performance
RTA	Required Time of Arrival
SARPs	Standards and Recommended Practices
SESAR	Single European Sky ATM Research
SID	Standard Instrument Departure
SOF	Safety of Flight Test
STAR	Standard Instrument Arrival
TMA	Terminal Manoeuvring Area
TSE	Total System Error
TSO	Technical Standard Order
VNAV	Vertical Navigation

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