INTERNATIONAL CIVIL AVIATION ORGANIZATION

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Agenda Item 6: Technical Cooperation development activities

STATUS OF GALILEO AND EGNOS PROGRAMS

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SUMMARY

Recognising the strategic importance of satellite navigation, its potential applications and the current GNSS systems shortcomings, Europe decided to develop its own GNSS capability in a two-step approach through the implementation of an SBAS type system called EGNOS to cover the short and medium term needs and through a full fledge satellite navigation constellation called GALILEO to support multimodal user needs for the longer term.

The current information paper presents a status report of both programmes that could provide significant benefits for the civil aviation community.

1. INTRODUCTION

Recognising the strategic importance of satellite navigation, its potential applications and the current GNSS systems shortcomings, Europe decided to develop its own GNSS capability in a two-step approach:

- EGNOS (European Geostationary Navigation Overlay Service) is the first European step in satellite navigation that will be operational by 2004. Europe is building EGNOS as an enhancement over GPS and the Russian GLONASS (GLObal NAvigation Satellite System) to provide, through a civil service, improved accuracy and integrity data. Similar initiatives are being developed in US (WAAS system) and Japan (MSAS system). The ICAO (International Civil Aviation Organization) international SBAS (Satellite Based Augmentation System) standards guarantee the interoperability of all these systems at user level. Besides its own specific operational objective as the European SBAS, EGNOS is a unique instrument to gain experience not only in the development of GNSS technology but also, most importantly, in the operational introduction of Galileo services.

- Galileo is the second step. EGNOS provides Europe with early benefits but does not provide Europe with a sufficient level of control over GNSS continuity of service and precision. The introduction of satellite navigation services on a very large scale and the implementation of the most stringent European regulations cannot be envisaged if users are fully dependant on a single system, without any degree of European control. Galileo represents the European objective of autonomy for this crucial technology. Galileo will also offer, alongside an open service similar to the GPS civilian service, new features to improve and guarantee services, thereby creating the conditions for responding to obligations imposed by critical, safety of life, or commercial applications. Galileo services are required to be fully compatible and interoperable at user level with other GNSS services, with no common failure mode between systems. This combined use of Galileo and other GNSS systems will offer better performances for all kinds of user communities all over the world.

This strategy is reflected in the EC communications on Galileo[1] [2], and in the Galileo resolution of the Council of the European Union[3]. The latter adopted the resolution, highlighting the objective of European role for such strategic technology for the benefit of our society and economy. ESA Member States agreed on an integrated strategic vision for the provision of European GNSS Services by the combined use of EGNOS and Galileo services[4].

2. EGNOS PROGRAM STATUS

The European Tripartite Group (ETG), (ESA – EC – EUROCONTROL) is implementing, via the EGNOS project, the first European contribution to the Global Navigation Satellite System which will provide and guarantee navigation signals for aeronautical, maritime and land mobile Trans-European network applications. On behalf of this tripartite group, the European Space Agency is responsible for the system design, development and technical validation of an Advanced Operational Capability (AOC) of the EGNOS system. The Technical validation is to be completed in April 2004, to enable operational use of the EGNOS Signal for safery of life applications in 2005.

2.1 EGNOS MISSION

EGNOS will provide significantly improved services with respect to GPS, in term of accuracy (from 20 meters to 1-2 meters), service guarantee (via Integrity signal) and availability (via additional ranging signals). It will operate on the GPS L1 frequency, and will thus be receivable with standard GPS front-ends. EGNOS is one of three Satellite-Based Augmentation Services (SBAS), the two others being the United States WAAS and the Japanese MSAS. The EGNOS coverage will first be the ECAC (European Civil Aviation Conference) area, and could be later extended to include other regions. EGNOS will meet, enhancing GPS and GLONASS, many of the current positioning, velocity and timing requirements of the land, maritime and aeronautical modes of transport in the European Region.

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[1] Commission Communication, "Galileo, Involving Europe in a New Generation of Satellite Navigation Services", COM (1999) 54 final, 10.02.1999
[2] Commission Communication on "Galileo", COM (2000) 750 final, 22.11.2000
[3] Council Resolution on Galileo, 7918/01, 5.04.2001
[4] ESA/PB-NAV(2001)29, rev.1

For civil aviation, EGNOS will comply with last DO 229C and SBAS SARPS requirements and will provide in ECAC an aviation service from En-route through APV-2 (VAL=20m; HAL=40m), in line to SARPS requirements for these operations.

2.2 EGNOS STATUS

The EGNOS programme was planned in two different phases: Initial phase and AOC Implementation phase; The EGNOS Initial Phase was successfully concluded in November 1998 with the System Preliminary Design Review (PDR), and has enabled the effective start of the Implementation phase by the end of 1998. On 24 May 2002 EGNOS achieved the successful closure of its Critical Design Review (CDR) moving into the last manufacturing/qualification phase.

At current stage (Feb 2003), most sub-systems are already qualified and has gone through a formal susbsystem Factory Qualification Reviews (FQR). In addition, all sub-systems are now available in early intermediate deliveries at the integration site and the system pre-integration activities have started.
Next milestones to come are:

- Emission of the first EGNOS signal (initial configuration, otherwise called SIS 0) April 2003;
- EGNOS factory Qualification review, planned for summer 2003;
- EGNOS final qualification through the Operational Readiness Review, scheduled for April 2004

The industrial team in charge of EGNOS AOC development is led by Alcatel Space Industries (France) with the participation of companies from ESA participating States. In addition, the EGNOS project includes significant contributions from the French Space Agency (CNES), the Norwegian Mapping Authority (NMA), and main European Air Traffic Management service providers. Those partners will in particular provide ESA with in-kind deliveries, including the infrastructure to host a number of the necessary EGNOS ground stations.

2.3 . The EGNOS System Test Bed (ESTB)

The ESTB (EGNOS System Test Bed) is a real-time prototype of EGNOS that became operational in January 2000. The ESTB has been developed with a set of objectives including:

- The support to EGNOS design: In particular, algorithm design benefits from the ESTB experience in design and usage.
- The demonstration of the capabilities of the system to users;
- The analysis of future EGNOS upgrades.

By using GPS and ESTB Signal-In-Space, users within Europe can nowadays determine their position with an error less than 1-2 meters (horizontal) and 3-4 meters (vertical), 95 percent of the time. The ESTB is also providing an integrity service.

For the period October/December 2002, the ESTB continuously transmitted a Signal In Space on the Inmarsat AOR-E providing an availability of service (accuracy and integrity) at 99.5%

for APV1 and about 95% for APV2. Continuous ESTB broadcast via the Inmarsat IOR satellite is available on a continuous basis since September 2002.

During the period 2000-2002, the ESTB has supported a large number of application demonstrations: The European Commission, national agencies and ESA are supporting this demonstration initiatives of European industry and operators in a number of ways.

2.4 EGNOS FUTURE POTENTIAL UPGRADES

EGNOS has been designed with built-in capabilities, which allow upgrading the EGNOS system without service interruption. At this moment ESA, EC and the GALILEO Interim Support Structure are assessing possible evolutions scenarios of EGNOS after 2004.

Current ideas include:

1- The extension of EGNOS service beyond current ECAC service area (e.g. by the introduction of additional reference stations);
2- The provision of EGNOS services through future SBAS GEOS in both L1 and L5 aiming at supporting robust satellite navigation service;
3- Provision of message type 28 (not currently provided in EGNOS) for provision of service beyond ECAC area;
4- Upgrade of reference stations to take advantage of the GPS L2C modernization feature, which could allow a much more robust ionospheric estimation;
5- Integration into GALILEO; Assessment of the most adequate integration aiming at providing to European users a GNSS "sole service" based on both GALILEO and the EGNOS service;
6- Provision of EGNOS signal through non-GEO means (e.g. wireless networks; etc);

2.5 EGNOS SERVICE EXTENSION PROGRAMS

AFI Region

The Africa and Indian Ocean (AFI) States have adopted a strategy to implement GNSS for aviation in their region. This has been approved by the International Civil Aviation Organisation (ICAO). The first phase of this strategy comprises the deployment of mobile

ESTB RIMS in the AFI region to extend the ESTB coverage. This will then be used to demonstrate an EGNOS APV 1 service over the AFI land-masses.

An initial activity in Dakar has recently been launched by the European Commission together with ASECNA (Agence Pour La Sécurité De La Navigation Aérienne En Afrique). This aims to provide an APV 1 signal in the Dakar area and to verify the performance in static and dynamic conditions.

The first preliminary results indicate that an APV1 test service is available about 95% of the time, and that vertical positioning accuracies of between 5 and 6 metres (95%) are being achieved. The dynamic flight trials were conducted in Dakar at the end of February. This is the first time that an ESTB RIMS has been deployed to deliver a service outside the core European Civil Aviation Conference (ECAC) area. Deploying the Dakar RIMS has been beneficial not only because it provides a service in the Dakar region, but also because it has enhanced the performance of the ESTB in the Mediterranean (from APV 1 to APV2) and further improved the performance of the ESTB in the Canary Islands. This has important implications for the extension of EGNOS services outside ECAC.

The follow up phase of the AFI region work plan include the deployment of a network of RIM stations through the region and the preparation for EGNOS operational implementation through numerous activities on system design and development, cost and funding aspects as well as institutional and operational frameworks.

Medium terms activities (2005-2011) will work on the implementation of operational applications meeting the APV I requirement throughout the AFI region.
Long term plan (2012 onward) will be built upon the existence of two independent constellations (GALILEO and GPS) to support sole means navigation services from en-route to Cat I operations.

CAR/SAM Region

During the last GREPECAS/11 meeting (Manaus, Brazil 3-7 Dec 2002) it was agreed to accept the European proposal to conduct EGNOS trials in the CAR/SAM Regions. These trials should be conducted under the mechanism of a specific ICAO technical cooperation project (RLA/03/902) and the members from Colombia, Cuba, COCESNA and Spain expressed the interest of their respective States/Organizations to join this project. This project is now under final review and approval. It will be presented during a meeting that will take place in ICAO HQ on March 2003.

To carry out the trials based on the ESTB-signal, the 3 reference stations will be deployed in the region and connected to the ESTB (EGNOS System Test Bed). A SBAS test signal will be provided by the Inmarsat AOR-E GEO satellite and different flight trials in the region will be conducted before summer 2003.

The EGNOS-type trials will provide useful information in support of the GREPECAS activities in the definition of the GNSS strategy for the region. Areas of cooperation with the WAAS trials have been identified (e.g. ionosphere, interoperability,..).

3. GALILEO PROGRAM STATUS

3.1 GALILEO MISSION

The definition of the Galileo services is based on a comprehensive review of user needs and market analysis. There will be some services provided autonomously by Galileo and other services resulting from the combined use of Galileo with local elements, EGNOS and other systems.

The Galileo satellite-only services services will be provided worldwide and independently from other systems by combining the signals broadcast by the Galileo satellites. There is a wide range of possible applications with different operational requirements that have been grouped around the following five reference services:

- Galileo Open Service (OS)
- Safety of Life (SoL).
- Commercial service (CS).
- Public regulated Service (PRS).
- Support to Search and Rescue service (SAR).

Open Service

The Galileo Open Service provides positioning, velocity and timing information that can be accessed free of direct charge. This service is suitable for mass-market applications, such as in-car navigation and hybridisation with mobile telephones. The timing service is synchronised with UTC when used with receivers in fixed locations. This timing service can be used for applications such as network synchronisation or scientific applications.

Safety Of Life Service

The target markets of the Safety of Life service are safety critical users, for example maritime, aviation and trains, whose applications or operations require stringent performance levels.

This service will provide high-level performance globally to satisfy the user community needs and to increase safety especially in areas where services provided by traditional ground infrastructure are not available. A worldwide seamless service will increase the efficiency of companies operating in a global basis, e.g. airlines, transoceanic maritime companies.

This service will be offered openly and the system will have the capability to authenticate the signal (e.g. by a digital signature) to assure the users that the received signal is the actual Galileo signal. This system feature, which will be activated if required by users, must be transparent and non-discriminatory to users and shall not introduce any degradation in performances.

The provision of integrity[5] information at global level is the main characteristic of this service. Non-European regions could also support the provision of this service on a regional basis by delivering regional integrity information through the Galileo satellites.

Commercial Service

The Commercial Service will allow the development of professional applications, with increased navigation performances and added value data, compared with the Open Service. The foreseen applications will be based on:

- Dissemination of data with a rate of 500 bps, for added value services;

[5] Integrity is the ability of a system to provide timely warnings to the user when it fails to meet certain margins of accuracy.

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- Broadcasting of two signals, separated in frequency from the Open Services signals to facilitate advanced applications such as integration of Galileo positioning applications with wireless communications networks, high accuracy positioning and indoor navigation.

Public Regulated Service
The PRS is envisaged to provide a higher level of protection against the threats to Galileo Signals in Space than is available for the Open Services (OS, CS and SoL). The Public Regulated Service will only be accessible for subscribed governmental users and be controlled through the encryption of the signals and the appropriate key distribution.
Governmental applications include Police and Law Enforcement services (EUROPOL, customs,…).

Support to Search and Rescue Services
The Galileo support to the Search and Rescue service - herein called SAR/ Galileo - represents the contribution of Europe to the international COSPAS-SARSAT co-operative effort on humanitarian Search and Rescue activities.

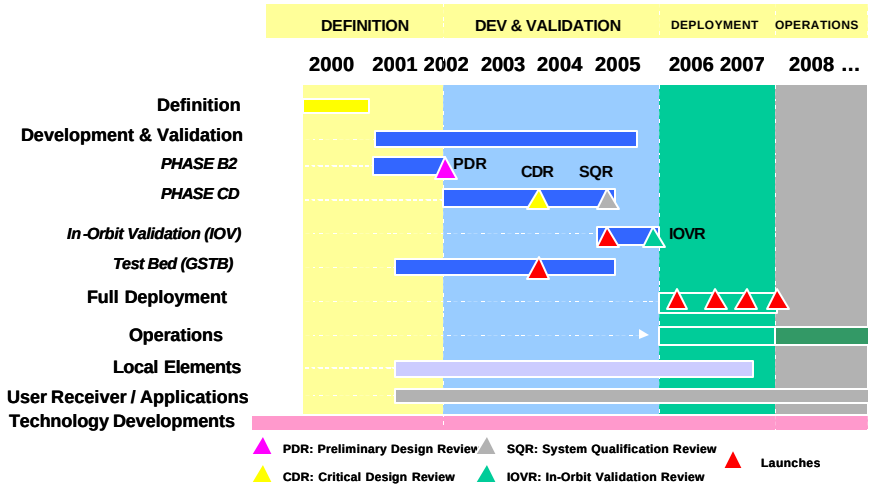
In addition, SAR/Galileo will introduce a new SAR function namely, the return link from the SAR operator to the distress emitting beacon, thereby facilitating the rescue operations and helping to identify and reject the false alerts.

3.2 GALILEO STATUS

The Galileo preliminary system design phase is now completed and ESA is preparing for the launch of development contracts for deployment of the infrastructure, including the launching of the first test satellites. Financing of this phase is provided jointly by the European Union and the European Space Agency for a total of 1.1 b€.

The GALILEO infrastructure will be implemented in three phases:

- *Development and validation phase (2002-2005)*
  - Consolidation of Mission Requirements;
  - Development of satellites and ground-based components;
  - Validation of the system "in orbit".
- *Deployment phase (2006-2007)*
  - Construction and launch of satellites;
  - Installation of the complete ground segment.
- *Operational phase (from 2008)*



In parallel with the system development, there are several activities launched with the objective to consolidate the service definition.

- Industrial support is provided to in the standardisation, certification, legal and economical domains in addition to more technical work on frequencies, design of receivers and local elements for GALILEO.
- User fora are als o organised on a regular basis to get feed back from different user communities on the GALILEO services.
- Finally, interaction with standardisation bodies, such as ICAO GNSSP for aviation, is actively pursued in order to match as much as possible GALILEO performance requirements with user expectations and to ease the introduction of GALILEO in future standards.

3.3 ORGANISATION OF THE PROGRAMME

For the implementation of the Development and Validation phase of the Galileo programme, the management approach will be structured in such a way as to ensure the unity of the management including the financial control of the programme.
The organisational scheme is centred on the establishment, by the European Commission and the European Space Agency, of a legal entity, i.e. the Galileo Joint Undertaking (JU), for a period of four years.

The main tasks of the JU are:

- to oversee the optimal integration of EGNOS in Galileo and the implementation of the Galileo development and validation phase;
- to oversee the research and development activities needed to successfully complete the development and validation phase, preparing the deployment phase;
- to help to mobilise the public and private funds needed for the deployment and operations phases, i.e.:

- to support the development of applications for the early introduction of services based on GALILEO
- to draw up a business plan covering all the phases of the programme,
- to negotiate an overall financing agreement setting out the responsibilities, roles and risk to be shared between public and private sectors, by way of a competitive tendering process (concession scheme)
- to supervise the carrying-out of all Galileo programme elements and to make any necessary adjustments during the development phase

Private entities can be invited to join the JU-structure once the tendering procedure of the concession has been finalised in order to avoid conflicts.

Through an agreement concluded between the Joint Undertaking and the European Space Agency, the latter is in charge of carrying-out the activities required during the Development and Validation Phase with regard to the space segment and the earth segment associated with the system.

4. CONCLUSIONS AND RECOMMENDATIONS

European Satellite Navigation Programs EGNOS and GALILEO are moving forward and will be widely useable for civil aviation operations.

The EGNOS system, designed under the ICAO SBAS concept, will soon become operational and, in combination with its US and Japanese counterparts WAAS and MSAS, will provide safe and improved navigation capability over extremely wide areas. Similar systems are being considered or already under development in several regions of the world (GAGAN in India, experimental systems implemented in Central and South America and extension of EGNOS tested in Africa and Middle East) that will further consolidate the role of SBAS in the civil aviation strategy for transition to satellite navigation. The experience gathered through the operational use of EGNOS by civil aviation will also be useful to speed up the introduction of services based on GALILEO.

The GALILEO program will deploy a full European satellite constellation, under civil control, that will strengthen the robustness of satellite navigation, alleviate a number of institutional concerns and should further facilitate a full transition to satellite

navigation. The use of the services offered by GALILEO will rely on the availability of ICAO standards and recommended practices covering the system.

The Panel is invited to :

1. Recognize the progress made in the implementation of EGNOS under the SBAS concept
2. Take into account the service soon to be provided by EGNOS and other SBAS systems when developing transition strategy and regional planning
3. Continue its effort to standardize GALILEO signal/services for civil aviation

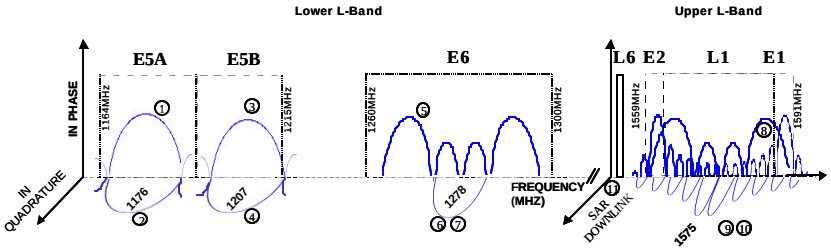
APPENDIX A

OVERVIEW OF GALILEO SIGNAL STRUCTURE

Ten navigation signals and one Search And Rescue (SAR) signal are provided by the satellite constellation. In accordance with ITU (International Telecommunication Union) regulations, Galileo navigation signals will be emitted in the RNSS allocated bands, and the SAR signal will be broadcast in one of the frequency bands reserved for the emergency services (1544-1545 MHz).

The following chart describes the Galileo navigation signals emission:

- 4 signals are transmitted in the frequency range 1164-1215 MHz (E5a-E5b)
- 3 signals are transmitted in the frequency range 1260-1300 MHz (E6)
- 3 signals are transmitted in the frequency range 1559-1591 MHz (L1)



Galileo Signal In Space Description

Signals id.	Signals	central frequency	modulation	chip rate	code encryption	data rate [6]	data encryption
1	data signal in E5A	1176 MHz	BPSK(10)	10 Mcps	no	50 sps/25 bps	no
2	pilot signal in E5A	1176 MHz	BPSK(10)	10 Mcps	no	no data	no data
3	data signal in E5B	1207 MHz	BPSK(10)	10 Mcps	no	250 sps/125 bps	no [7]
4	pilot signal in E5B	1207 MHz	BPSK(10)	10 Mcps	no	no data	no data
5	spilt-spectrum signal in E6	1278 MHz	BOC(10,5)	5 Mcps	Yes – governmental approved	250 sps/125 bps	yes
6	commercial data signal in E6	1278 MHz	BPSK(5)	5 Mcps	Yes - commercial [8]	1000 sps/500 bps	yes
7	commercial pilot	1278 MHz	BPSK(5)	5	Yes –	no data	no data

[6] using a 1/2 rate Viterbi convolutional coding scheme
[7] A capability of encryption for integrity is envisaged and may be activated pending results on potential market interest for integrity
[8] This encryption may be maintained or removed pending on market analysis results

	signal in E6			Mcps	commercial[9]		
8	spilt-spectrum signal in L1	1575 MHz	BOC(n, m) [10]	m Mcps	Yes – governmental approved	250 sps/125 bps	yes
9	data signal in L1	1575 MHz	BOC(2,2)	2 Mcps	no	200 sps/100 bps	no [11]
10	pilot signal in L1	1575 MHz	BOC(2,2)	2 Mcps	no	no data	no data

Table 1 *Galileo signal characteristics*

Services allocation within Galileo signals
Both the ranging code and data carry the specific information needed for a specific service. Among the 10 navigation signals:

- 6 are designed for OS and SoL (signals 1,2,3,4,9,10)
- 2 are designed specifically for CS (signals 6,7)
- 2 are designed specifically for PRS (signals 5,8)

Table 2 summarises the navigation signals characteristics and their service allocation:

		Navigation Services				Signals characteristics	
Signals id.	Frequencies	OS	CS	SoL	PRS	Ranging Code Type	Data Type[12]
1,2,3, 4,9 and 10	E5a E5b L1	X	X	X		Open Access	Navigation data Integrity data SAR data[13], Commercial data[14]
6, 7	E6		X			Commercial encryption	Commercial data
5,8	E6 L1				X	Governmental encryption	PRS data

Table 2 *Navigation signals characteristics and their service allocation*

[9] This encryption may be maintained or removed pending on market analysis results
[10] n and m operational values are the subject of on-going technical trade-o
[11] A capability of encryption for integrity is envisaged and may be activated pending results on potential market interest for integrity
[12] Pending final service data allocation
[13] This SAR data correspond to the information sent from SAR operators to the distress emitting beacons: alert acknowledgement, coordination of rescue teams.
[14] Possibility to include commercial data is under assessment

Note: The SAR distress messages (from distress emitting beacons to SAR operators), will be detected by the Galileo satellites in the 406-406.1 MHz band, and then broadcast to the dedicated receiving ground stations in the 1544-1545 MHz band, called L6 (below the E2 navigation band). The SAR data, from SAR operators to distress emitting beacons, will be used for alert acknowledgement and co-ordination of rescue teams, and will be embedded in the navigation data of the Open Service Signal emitted in the L1 band.

-END-