AGENDA ITEM 4.3: EUROCONTROL Policy on GNSS for Navigation Applications in the Civil Aviation Domain

EXECUTIVE SUMMARY:
This EUROCONTROL policy on GNSS is based on a gradual reliance on Satellite navigation that has as final goal its use as sole service, to the extent that this can be shown to be the most cost beneficial solution and if is supported by a successful safety and security analyses. The vision for implementing this policy is based on the combined use of signals coming from at least two constellations in diverse frequency bands. User receivers will process signals from different GNSS constellations in combination with augmentations (e.g. ABAS, GBAS or SBAS depending on individual business cases and the phase of flight). This vision is in line with the “Common aviation Community position on GNSS” endorsed by the Provisional Council of EUROCONTROL.

The paper and its annex present the operational, technical, economic, institutional and legal aspects that are the basis for a long term vision based on a multi-constellation and multi-frequency GNSS, as the positioning and timing source for Navigation applications in civil aviation.

This GNSS Policy aims at establishing a common vision among all aviation stakeholders to jointly proceed towards a successful transition to GNSS. This policy is complementary to the Navigation Strategy as GNSS is the cornerstone of future navigation from an infrastructure perspective. This document also sets policy guidelines on GNSS to be applied in the SESAR implementation phase.

This paper includes specific policies for EGNOS, GBAS and an updated position regarding the Galileo SoL service. Members of ANT endorsed this document in October 2007 (ANT/44 meeting). The document describes some principles related to the transition towards GNSS.

A second GNSS policy paper covering also other civil applications (i.e. ADS-B, A-SMGCS and timing) and the use of GNSS for military applications will be prepared in coordination with the involved units of the Agency. It is intended to submit this document to the SCG in the future.

RECOMMENDATION
Members of the SCG are invited to endorse this policy on GNSS for navigation applications in the civil aviation domain.
1 GNSS Policy: objectives

This document:

- Aims at establishing a common vision among all aviation stakeholders in Europe to jointly proceed towards a successful transition to GNSS.
- Sets policy guidelines on GNSS for the SESAR implementation phase.
- Includes specific policies for EGNOS and GBAS.
- Provides a more consolidated position with respect to the need of the Galileo SoL service in aviation.
- Describes some principles related to the transition towards GNSS.


This EUROCONTROL policy on GNSS is based on a gradual reliance on Satellite navigation that has as final goal its use as sole service, to the extent that this can be shown to be the most cost beneficial solution and if is supported by a successful safety and security analyses. The vision for implementing this policy is based on the combined use of signals coming from at least two constellations in diverse frequency bands. User receivers will process signals from different GNSS constellations in combination with augmentations (e.g. ABAS, GBAS or SBAS depending on individual business cases and the phase of flight).

The overall context in terms of terms of technical, safety, security, operational, economic and legal aspects that constitute the basis for this policy is detailed in Annex 1. This Annex also includes some considerations regarding the feasibility of the sole service concept.

There are still uncertainties in different aspects (e.g. technical, economic,..) that may affect this vision depending on how the GNSS context evolves. In particular, in the absence of a GNSS pricing policy for aviation from the EU, it is assumed that a service fee will be levied for the EGNOS and the Galileo SoL services. The existence of a service fee is being detrimental for the acceptance of these services in aviation and it is recommended that these services will be provided for free to aviation as a public utility if there is no practical and cost effective way to implement a pricing policy that would ensure non-discrimination and fairness principles between categories of users and within aviation.

There is no GNSS solution that fits all user sizes and all ANSPs. Each aviation stakeholder will chose the GNSS solution that can meet operational and safety requirements in the most cost effective way.

The expected evolution on GNSS systems will allow a progressive improvement in terms of user performances and systems robustness that will overcome all, or most of, current GNSS deficiencies. This vision is considered to be the optimal scheme in terms of performance, robustness and independence from a single GNSS operator.

Aviation welcomes the agreements on the signals for GPS and Galileo between US and the EU, in terms of frequency bands and common design that will facilitate the interoperability at user level.

For en-route and terminal area:

- A total PBN environment will enable improved flexibility of airspace design and increased efficiency of aircraft operations. There are several technical options, or combinations of them, potentially capable of supporting the required specification (i.e. Advanced RNP 1); a free GNSS service provided by at least 50 multi frequency satellites from at least two constellations enhanced at aircraft level (i.e. ABAS based on inertial coupling and/or RAIM functionality), EGNOS and the Galileo SoL service. Individual business cases will determine the most adequate solution for each stakeholder.
A rationalised DME network. A back-up with a dissimilar-technology covering GNSS remaining deficiencies (e.g. jamming and solar storms). The progressive reliance on GNSS and the mitigation of all GNSS deficiencies could result in a complete withdrawal of ground navigation infrastructure in the very long term (2030+).

For approach and landing:

- ILS will remain the primary source of guidance for CAT I/II/III operations in major airports. GBAS will increasingly support CAT II/III operations where economically beneficial once enhanced GPS and Galileo become available. It is assumed that all GBAS for CAT I stations will be upgraded to CATII/III stations.

- APV operations shall allow the discontinuation of conventional NPA procedures in all ECAC airports. Based on the signals coming from different constellations (e.g. GPS and Galileo), there are several technical options, or combinations of them, potentially capable of supporting APV operations: ABAS based on inertial coupling, EGNOS, Galileo SoL, ABAS based on new RAIM algorithms and BaroVNAV. There are still uncertainties on the final capabilities of these options (e.g. Galileo SoL performance, the actual performance of new RAIM algorithms). These technical options will require procedures with different Decision Heights for the same runway to maintain required safety levels, and individual business cases will determine the most adequate solution for each stakeholder.

This vision for GNSS is considered to be the most cost-effective way a providing positioning and timing information to meet the operational requirements of the Airspace strategy and the SESAR operational concept for the long term (2020+).

The issues related to the complexity of the multiconstellation receiver including augmentations (e.g. ABAS, GBAS or SBAS depending on individual business cases and the phase of flight), will have to be addressed in coordination with appropriate standardisation groups (e.g. EUROCAE WG 62) with due consideration to performance, safety, robustness and economic aspects.

3 Policy on GBAS

ILS systems are providing a very efficient service today for precision approach and landing operations. It is recognised that there will not be a rapid transition from ILS to GBAS and that an ILS network will be maintained for the foreseeable future. However, ILS systems are facing some problems in terms of multi path effects, dimension of the sensitive areas and frequency spectrum constraints that are becoming progressively more critical. Airports may overcome these problems by implementing GBAS.

In addition, GBAS has the capability to support more advanced operations, than those based on the ILS look alike concept, and therefore provide operational benefits in terms of:

- Allow for enhanced flexible approaches in a seamless way, such as high performance RNP approaches and multiple approaches to a single runway (linked to advanced controller aids).
- Increase flexibility of airport runways by enabling all runways of an airport simultaneously.
- Maintain airport throughput during low visibility operations.
- Increase closely spaced parallel approach availability
- Provide Take Off, departure and missed approach guidance as well as navigation on the airport surface.

The GBAS standard was initially developed as a replacement of ILS and consequently has been designed under the concept of ILS look alike in order to reduce its cost to the airlines. But that concept has some major limitations and one of them is to significantly limit benefits that could be obtained exclusively from GBAS, especially at European level where ILS are wide spread. The cost benefit analysis based on this concept made by EUROCONTROL concluded that, in the short term, the ILS scenario is by far the most cost efficient solution to support the ILS look alike concept of operations mainly due to the high retrofit costs in the GBAS airborne side, and the limited benefits to be expected especially for CAT I operations.

Notwithstanding the current results of the overall Business Case study, the implementation of GBAS can be economically viable and operationally acceptable on a local basis for an increasing
Concept of operations: it is expected that the concept of operations for precision approaches and landings will evolve progressively, away from the current ILS look alike concept to an advanced concept\(^1\) due to operational and environmental needs. Other elements needed to enable this concept of operations (e.g. controller tools and autopilot updates) are under development, but their implementation is outside the scope of this policy and dependent on additional factors.

Safety: Safety analysis will provide the adequate assurance level commensurate with the degree of reliance being placed upon the GBAS service and will indicate the dimension and the nature of potential backup services to be retained.

Technical and standardisation aspects: GBAS CAT I stations are considered to be an interim step towards the development of GBAS CAT II/III stations. It is expected that GBAS standards and developments will ultimately support CAT II/III operations based on the combined use of signals coming from different constellations (i.e. GPS, Galileo and GLONASS). Current developments at technical and standardisation level aim at achieving CAT II/III capabilities based on GPS L1 only. In this case, provisions to allow the transition from current developments to a multiconstellation scheme should be made.

Airborne aspects: Airborne related cost is one of the key drivers in the transition from ILS to GBAS. To limit that cost to the airlines avionics package will have to include GBAS. It was initially expected that just a few aircraft would be retrofitted with GBAS equipment but the number of retrofit will largely depend on the retrofit avionic package definition and the associated cost. Regarding forward fit, GBAS cost should be very limited as already most commercial aircraft manufacturers offer GBAS CAT I capability as optional equipment, and some new aircraft will have GBAS as standard equipment.

Operational implementation: GBAS CAT I operational approval will be the first key achievement towards GBAS operations. The GBAS CAT I stations deployed in Europe will allow to progress on the GBAS validation activities and to increase operational experience to enable and encourage the development of GBAS applications, CAT II/III and high performance RNP operations. Work performed on GBAS concept of operations has highlighted that significant effort must be done at ICAO level in order to consolidate the concept and to ensure harmonised operations.

The EUROCONTROL policy on GBAS is to support a progressive, harmonised and cost effective transition towards GBAS across ECAC by supporting the development of the above mentioned enablers.

4 Policy on EGNOS

EGNOS is expected to be certified according to the SES regulations by 2009/2010. EGNOS can provide operational benefits to different categories of airspace users (e.g. General Aviation, Helicopters, Business jets, Regional Airlines) offering a cost-effective option to meet PBN requirements and supporting LPV operations at runways not equipped with ILS. The EUROCONTROL ECIP (European Convergence and Implementation Plan), includes a specific objective (NAV 08) aiming at enabling the implementation of approach procedures with vertical guidance using EGNOS in five European States (France, Germany, Spain, Italy and Switzerland). EUROCONTROL is contributing to the operational validation of EGNOS according to aviation requirements. EUROCONTROL provides a toolkit related to the operational introduction of EGNOS and is coordinating activities at European level.

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\(^1\) The precise definition of the advanced concept of operations is under development. The main principle of this concept is to allow a more flexible transition from an FMS-based approach (RNAV/RNP) to a (short) GBAS approach, taken advantage of the GBAS-inherent system characteristics to overcome operational limitations of ILS. This may include, but is not limited to:

- shortening the straight part of the approach to the operationally required minima (aircraft stabilization);
- optimising capture flight paths (constant descent profiles);
- use the capability of GBAS to provide high-integrity, high accuracy position information in the terminal area (Positioning service);
- exploit the capability to provide multiple, concurrent, approaches to the same runway (different angles or thresholds to more efficiently perform wake vortex separation);
- investigate the ability to perform capture at multiple points more efficiently (no risk of false captures) with help of arrival managers.
EGNOS has a higher capability to reduce minima than BaroVNAV, which its minima reduction capability is constrained by the altimetry error. EGNOS is expected to provide 250 ft minima and an ILS look-alike approach capability on most European runways. In a second step is expected to evolve toward a Cat I capability (200 ft minima). This evolution will be similar to the WAAS evolution to 200 ft minima, implemented in 2007 in the US.

However, EGNOS provides little performance benefit to first level commercial aircraft (i.e. equipped with RNP approach and BaroVNAV systems). Most of the airlines do not plan to invest in equipping their aircraft with EGNOS and are against paying for this service. IATA requires that whenever States are providing geometrical vertical guidance at a certain airport, that such procedures must be complemented by BaroVNAV procedures where it is needed for BaroVNAV capable aircraft operating in these airports. Airspace users are not collectively willing to pay for EGNOS services and the major air transport airlines request that EGNOS related costs shall not be allocated to airspace users not equipped with EGNOS.

In the long term, the overall added value of an augmentation system like EGNOS will depend on the actual level performance of ABAS solutions in a multiconstellation and multi frequency GNSS environment. Anyway, EGNOS will improve the overall robustness of GNSS and can be used as a GPS monitoring tool for States. In particular, the availability of the ionosphere model broadcast by EGNOS could be a very valuable mitigation to cope with some of the effects the solar activity on the GNSS signals, which is one of the major technical obstacles of the sole service concept.

Individual business cases will determine the suitability of EGNOS for each aviation stakeholder. If there are no significant operational benefits that can be exclusively obtained from a service for which a fee will be charged, ANSPs and airspace users will choose other options (e.g. a free GNSS service provided by at least 50 multi frequency satellites from at least two constellations enhanced by a new RAIM algorithm2 functionality) that are free of charge and can meet operational and safety requirements in a more cost efficient way.

Current uncertainties about EGNOS in terms of date of its operational introduction, life-time period, institutional issues and charging policy are impeding some ANSPs and airspace users to take their business decisions.

There are already SBAS receivers certified for aviation available. It is expected that progressively all new GNSS aviation sensors and receivers available in a multiconstellation era will be SBAS compatible receivers. Airspace users need to know the charging policy related to EGNOS when making business decisions in respect of the capabilities of their future GNSS receivers. The pioneer EGNOS users need to have guarantees that the lifetime of the service would allow them to amortize their investment. ANSPs have the elements to start preparing the operational implementation of EGNOS based procedures in their airspaces, but they do not have the necessary inputs for their business decisions.

It is very unlikely that a practical and cost effective way of implementing a fair and non-discriminatory charging scheme for EGNOS between communities of users and within the aviation community will be established. In this case, **EGNOS signals should be provided for free to aviation as a public utility.** In this context, the aviation community welcomes the EC proposal to the EU Council and Parliament to fund all EGNOS operational cost with EU funds for an initial period of 6 years. Nevertheless it has to be mentioned that the proposed period is determined by the EU financial perspective (until 2013), that is inconsistent with the aviation life-cycles.

The prompt completion of the system, the certification of its Service Provider and the clarification of the uncertainties about its charging policy, liabilities regime and life-time have to be achieved as a matter of urgency. A positive political declaration for the long term public financing of EGNOS will clarify some uncertainties and would provide the necessary stability to encourage ANSPs and airspace users to proceed with the operational introduction of EGNOS.

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2 Results of on-going studies carried out by EUROCONTROL and other entities shows that RAIM is a promising technique to provide vertical guidance in nominal and degraded conditions (e.g. multiple failure and loss of one frequency). Technical feasibility still to be fully confirmed.
5 Updated position of the aviation community on the Galileo SoL service

During the consultation process for the Galileo MRD, EUROCONTROL, representing the aviation community in Europe, already questioned the need for the Galileo Safety-of-Life Service. In view of this EUROCONTROL decided to undertake the specific studies to analyse:

- The extent to which aviation navigation applications rely upon a single data source.
- The provision of a global versus regional integrity services
- Integrity services required for the specific stringent operations,
- Capabilities of RAIM in the future environment of enhanced GPS and Galileo.

These studies consider a wide cross-section of users to ensure that the requirements of all of them are considered.

One of the current MRD requirements for the Galileo SoL service is to support APV-II operations worldwide based only on this service. Considering safety, performance and independence from single operator aspects, it can be concluded that the aviation community does not intend to use Galileo signals solely, in nominal conditions. Aviation will use Galileo signals in combination with signals from other constellations like GPS, and augmentations (from space, ground or the aircraft) as appropriate.

It should be noted that standardization fora (e.g. ICAO, EUROCAE) have however indicated that combined constellation receivers should avoid unnecessary complexity, which would increase costs in avionics design, testing and installation. In this respect, it is assumed that at least the first generation of combined constellation receivers will be limited to dual constellation receivers (e.g. GPS and Galileo); this is the current working assumption of EUROCAE and RTCA.

The mismatch between the aviation operational concept and the current requirements for the Galileo SoL would result in an over-dimensioned and costly infrastructure considering that aviation intends to use Galileo in combination with other GNSS elements. Moreover, aviation needs shall not be considered as the driver element for the development of the Galileo SoL service.

The preliminary results of on-going studies with respect to the capabilities of the new RAIM algorithms based on free signals in a multi constellation and multi frequency GNSS environment, indicate either the potential for RAIM to support standalone APV operations with GNSS vertical guidance, or at least the potential for alleviating the requirements (and design costs) of ground integrity channels (like Galileo SoL). These preliminary results will have to be consolidated considering in particular the performance of a RAIM based solution in degraded modes (e.g. loss of one frequency or loss of one constellation).

The aviation community waits the prompt availability of the Galileo Open service as a key element of the new GNSS environment, but with elements available yet, the aviation community can not derive exclusive operational benefits from the Galileo SoL and therefore strongly questioned its need if a service fee would be levied for it.

It is suggested that that the Galileo SoL requirements for aviation should be reviewed considering a multi constellation operational concept and the availability of regional, local and aircraft based augmentations.

This exercise would result in a better apportionment of requirements to Galileo resulting in a more cost efficient way of providing the robustness and performance levels (in nominal and degraded modes) as required by aviation. In parallel a trade-off based on operational and economic aspects would indicate the extent to which ground based navigation aids can be phased out compared with the performance and robustness that Galileo will bring to GNSS.

6 Transition towards GNSS

To take full advantage of the GNSS capabilities, a cost effective transition towards GNSS shall be pursued driven by operational requirements with due consideration to safety, technical, security, economic and legal factors. GNSS implementation shall be based on cohesive benefit-driven technical choices backed by realistic system development plans and political commitments.

As there is already an effective navigation infrastructure throughout the Europe and the costs to airspace users of transitioning to a new system are high, a cost effective transition towards a GNSS will be long.
There will be a progressive reliance on GNSS as performance and robustness will increase, being the final goal its use as sole-service for all phases of flight, to the extent that this can be shown to be the most cost beneficial solution and is supported by a successful safety and security analyses.

Costs of transition to new navigation systems and concepts are mainly driven by the airborne installation costs and when installation/retrofitting/certification costs outweigh operational benefits evolutions are postponed to the availability of new aircraft.

There will be many aircraft equipped with GPS receivers (with Aircraft, Ground or Space based augmentations) before certified multi-constellation receivers become available. Considering the amortisation of the investment made, these receivers will not be updated to multi-constellation GNSS receivers if the retrofitting cost outweighs operational gains.

In the case of GBAS, once equipment and standards are developed to support precision approach and landing in CAT II/III conditions, it will provide a viable alternative to ILS while offering a number of technical and operational advantages. A transition to GBAS from ILS may be enabled through updates of the aircraft’s Multi-Mode Receiver, which is becoming standard equipment on all large aircraft.

The inclusion of multi-constellation GNSS receivers within the ‘SESAR avionic package’ could be a cost effective scheme to combine the navigation updates with technological updates needed for surveillance or communication applications in one-shot.

At least in its initial phases, the transition towards GNSS it will require significant funding to support the development of applications enablers (e.g. design and validation of new flight procedures, pre-operational trials, mitigation of GNSS interferences, safety assessments, etc.) and incentives to airspace users to install GNSS equipments. The preferable source would be public funding through EU. Public funding shortcomings would result in a much longer transition, linked primarily to the availability of aircraft equipped from new with the GNSS capability.

7 Recommendation

Members of the SCG are invited to endorse this policy on GNSS for navigation applications in the civil aviation domain.
Annex 1: GNSS Policy framework

1 Introduction

EUROCONTROL is the European Organisation for the Safety of Air Navigation. This civil and military Organisation which currently numbers 38 Member States has as its primary objective the development of a seamless, pan-European Air Traffic Management (ATM) system.

EUROCONTROL has had a long involvement in GNSS matters at European and international level. The EUROCONTROL policy on GNSS is part of a multi-modal strategy in Europe, through co-operation with the EU and ESA, and contributes to the global vision for aviation, to be achieved through co-operation with ICAO, the FAA and other international partners.

EGNOS is a project of the European Tripartite Group whose members are the European Space Agency, the European Commission and EUROCONTROL. EUROCONTROL has a cooperation agreement with the GSA (European GNSS Supervisory Authority). EUROCONTROL is observer to the ESA PBNAV (Programme Board of Navigation) and the GSA Administrative Board.

EUROCONTROL is a founder member of the SESAR Joint Undertaking. The SESAR Programme (the Single European Sky ATM Research Programme) is undertaking actions to move towards an efficient global and integrated Air Traffic Management system defined and supported by all its stakeholders. GNSS is a key navigation component of SESAR for 2020 onwards.

EUROCONTROL is contributing to the development of GNSS applications addressing technical, operational, economic, institutional and legal matters in coordination with key European and international stakeholders. EUROCONTROL, in coordination with its aviation stakeholders, is defining the needs of civil aviation regarding GNSS and playing a major role in the operational validation of EGNOS according to the aviation requirements.

2 Background

In 2002, the Provisional Council of EUROCONTROL endorsed a “Common aviation Community position on GNSS”. This document sets the final goal concerning the use of GNSS in aviation: “if world-wide GNSS is the most cost beneficial solution, and is supported by a successful safety analysis, it should become the sole service navigation system, for positioning and timing data, for all phases of flight.”

Today, GPS offers a very efficient service and with adequate augmentation, is being used as a positioning source for B-RNAV (Basic Area Navigation), NPAs (Non Precision Approaches) and RNAV (Area Navigation) approaches. It has been estimated that around 70 % of the flights over ECAC are made by aircraft equipped with GPS. However, GPS has some deficiencies impeding its comprehensive use in aviation (e.g. number of satellites, single frequency and low power signal and the lack of integrity and single operator). The expected GNSS developments (e.g. more constellations like Galileo and more powerful signals in more frequency bands) will overcome most of the current GNSS deficiencies enabling the provision of enhanced positioning services for all phases of flight, for ground movements at airports and for automatic dependent surveillance-broadcast (ADS-B) applications.

For en-route and terminal area operations, the transition to GNSS cannot be isolated from the progressive introduction of the PBN (Performance Based Navigation) concept which comprises both RNAV X RNP X specifications that defines the capabilities required for an aircraft to navigate in a particular airspace segment as well as the navigation infrastructure.

The implementation of PBN and the introduction of GNSS run in parallel in Europe. GNSS is foreseen to become the main source of positioning data for en-route and terminal area operations since GNSS can support the most challenging PBN applications.
For approach and landing operations down to Cat I, it is expected that conventional non precision approaches (NPA) will be progressively replaced by standalone RNAV approach operations. These RNAV approaches will also be implemented as a backup of ILS Cat I. Depending on local business case and coordination with users, some ILS Cat I (small airfields) are also expected to be replaced by SBAS or GBAS based approaches.

For Cat II/III precision approach and landing, a gradual move from ILS to GBAS is expected at European airports, as GBAS has the capability to provide additional benefits and it becomes increasingly difficult to provide Cat III operations based on ILS due to multi path effects, dimension of the sensitive areas and radio spectrum capacity constraints.

ICAO (International Civil Aviation Organization) defines global standards to maintain safety levels which form the basis for the certification processes. ICAO does not require the use of a specific system, but allows the aircraft operator the choice of specific equipment to achieve the required capabilities. The required capability could be supported by either GNSS, the current ground based navigation infrastructure, airborne systems or a combination of them. The choice of the technology is, in all cases, cost and benefit driven.

The EUROCONTROL ‘Navigation Strategy for ECAC’ and its Implementation Plan support, the recommendations of the ICAO Global Air Navigation Plan for CNS/ATM Systems, as amended by the recommendations of the Eleventh ICAO Air Navigation Conference ANC/11 in particular with respect to Recommendation 6/1 – Transition to Satellite Based Air Navigation- which recommends that:

- ICAO continue to develop as necessary, provisions which would support seamless GNSS guidance for all phases of flight and facilitate transition to satellite-based sole navigation service with due consideration of safety of flight, technical, operational and economics factors;
- Air Navigation Service Providers move rapidly, in coordination with airspace users, with a view to achieving, as soon as possible, worldwide navigation capability to at least APV 1 performance; and
- States and airspace users take note of the available and upcoming SBAS navigation services providing for APV operations and take necessary steps towards installation and certification of SBAS capable avionics.

GNSS is a key positioning system to support the navigation system defined in the SESAR Programme. The European Community expectations for SESAR are to improve safety by a factor of 10 and to reduce costs to the airspace users (at least 50% less). In line with this view, the transition towards GNSS in aviation aims at increasing efficiency and safety while reducing navigation costs.

3 GNSS Policy: framework

This GNSS policy considers the strategies of aviation stakeholders in a framework that comprises technical, safety, operational, security, economic, institutional and legal aspects.

The final goal of having GNSS as sole service remains, but its feasibility still has to be demonstrated. The EUROCONTROL GNSS Work Plan, which is under preparation, will include some specific activities devoted to assess its feasibility. It is recognised that, at least for the foreseeable future, a rationalised terrestrial infrastructure must be retained until sufficient experience and confidence has been gained to validate GNSS operations.

Unfortunately, there are still significant uncertainties in the GNSS framework and important delays in some systems developments that are impacting the transition towards GNSS. However, this fact shouldn’t prevent stakeholders from taking the necessary actions to make possible that the final goal will eventually be achieved. A short description of the main related aspects defining the GNSS framework is provided below.
3.1 OPERATIONAL ASPECTS

The evolution of the operational requirements for navigation applications is based on:

- The progressive implementation of the PBN concept for en-route and terminal area operations, to achieve a total RNAV environment, and enable improved flexibility of airspace design and increased efficiency of aircraft operations;
- The replacement of conventional NPAs operations by APV operations.
- The continuation of the ILS look-alike concept and the progressive introduction of advanced\(^3\) operations concept for precision approach and landing where operationally or environmentally required.

The following summarises the expected operational environment evolution over time, without indicating any system or technology:

2007 – 2015

For en-route and terminal area:
- BRNAV for en-route above defined flight levels.
- Increased application of P-RNAV in TMA extending where required for en-route in accordance with the PBN concept implementation.

For approach and landing:
- Progressive introduction of APV operations replacing conventional NPAs operations.
- Continuation of the ILS look-alike concept of operations for Precision Approach and Landing.

2015 - 2020

For en-route and terminal area:
- Transition to a total PBN environment with a RNP 1 specification.

For approach and landing:
- Continued introduction of APV operations with a reduction in DH, replacing remaining conventional NPAs operations.
- Continuation of ILS look-alike concept and initial introduction of advanced concept for Precision Approach and Landing where operationally required.

2020+

For en-route and terminal area:
- Total PBN environment. Application of Advanced RNP 1 specification, extended to give 4D capability.
- All non-RNAV routes will be removed.

For approach and landing:
- Replacement of all conventional NPAs operations by APV operations.
- Continuation of ILS look-alike concept and progressive introduction of advanced concept for Precision Approach and Landing where operationally required.

\(^3\) The precise definition of the advanced concept of operations is under development. The main principle of this concept is to allow a more flexible transition from an FMS-based approach (RNAV/RNP) to a (short) GBAS approach, taken advantage of the GBAS-inherent system characteristics to overcome operational limitations of ILS. This may include, but is not limited to:

- shortening the straight part of the approach to the operationally required minima (aircraft stabilization);
- optimising capture flight paths (constant descent profiles);
- use the capability of GBAS to provide high-integrity, high accuracy position information in the terminal area (Positioning service);
- exploit the capability to provide multiple, concurrent, approaches to the same runway (different angles or thresholds to more efficiently perform wake vortex separation);
- investigate the ability to perform capture at multiple points more efficiently (no risk of false captures) with help of arrival managers.
3.2 ASPECTS RELATED TO THE FEASIBILITY OF THE SOLE SERVICE CONCEPT

The impact of GNSS SIS failures upon ATM is more critical than the impact of failures of individual terrestrial navaids due to the size of the airspace that could be affected. Studies show that intentional interference (i.e. jamming) and the effect of the solar activity on the GNSS signals are two major obstacles for the achievement of sole–service concept. However, it has not been proved that adequate mitigation measures cannot cope with these problems.

Adequate spectrum protection and security measures will have to be put in place to mitigate the effect of unintentional and intentional interference in all GNSS frequency bands.

Concerning the effects of the solar activity on the GNSS signals, the adequate monitoring and prediction of the space weather and the availability of technologically advanced receivers are the main mitigations against the effects of the solar activity on the GNSS signals that will become progressively more numerous and robust. The availability of the ionosphere information broadcast by EGNOS could be a very valuable element to mitigate the effects the solar activity on the GNSS signals.

Receivers with the adequate design are able to track L1 and L2 frequencies even under very intense solar radio burst conditions such as the recent event that was experience on December 2006. Moreover, the probability of losing GNSS signals due to the scintillation effects in mid-latitude areas where ECAC is located is remote. The sun exhibits an 11-year cycle in its activity and the next maximum is expected in 2011. A dedicated activity of the EUROCONTROL GNSS Work Plan will be devoted to the assessment of all potential effects of the solar activity over ECAC (e.g. scintillation, solar burst and fast-moving ionosphere gradients) and the efficiency of the identified mitigation measures.

Operational experience will determine the severity and likelihood of the GNSS failures and the effectiveness of the associated mitigations/alleviation actions.

The extensive use of ABAS (Aircraft Based Augmentation Systems) including inertial systems will mitigate the consequences of GNSS failures, in particular for en route and terminal operations. A trade-off based on safety, security, economic, operational aspects and the effectiveness of the mitigation measures, will define the best balance between the level of GNSS robustness and the size of backup network of traditional navaids (e.g. number of DMEs and ILSs) that would be needed in the long term considering also the ATC workload in the event of a GNSS services failure.

For further information on the decommissioning process of the different terrestrial navaids please refer to the document Navigation Infrastructure Planning 2020 and its annexes (Ref ANT/44 WP 13).

3.3 TECHNICAL ASPECTS

3.3.1 GNSS systems developments

According to current plans of major international players, there will be significant progress in GNSS in terms of modernisation of existing constellations (enhanced GPS and modernised GLONASS) and the launch of new ones (e.g. Galileo and COMPASS). However, there are uncertainties about the actual performance of future systems and their real implementation schedule.

As part of the GPS modernisation plan, it is foreseen that 24 GPS satellites (GPS IIF and GPS III) will broadcast the new L5 frequency by 2015 (TBC) and that the GPS III system will be deployed around 2018 (TBC).

Considering the current Galileo Programme status, it is expected that the deployment of 30 satellites will allow reaching the Galileo FOC (Full Operational Capability) by mid 2013. However, more time will be required to authorise Galileo for aeronautical use. ESA is finalising EGNOS developments and the system is expected to be certified for aeronautical use by 2009/2010.
The modernisation process for GLONASS is on-going and it is expected that 24 satellites will be operational by 2010.

The US and EU continue to work on the definition of GPS and Galileo signals that will facilitate the interoperability at receiver level. The decision on the potential adoption of the CDMA modulation by GLONASS would facilitate future interoperability with GPS and Galileo. The decision by the Russian authorities is due in 2007.

China has launched a MEO satellite of the COMPASS constellation but the Chinese authorities have not made any declaration to ICAO regarding the potential use of COMPASS for international civil aviation applications.

Concerning GBAS, some CAT I stations have been deployed in Europe and different trials are being performed in different ECAC States. Standardisation and Industrial activities related to the GBAS CAT II/III are progressing and it is expected that CAT II/III stations will be available around 2015 (TBC).

The official implementation schedules can suffer delays due to technical, managerial, financial or political issues. In particular for the European GNSS Programmes, it has to be highlighted that considering complexity of both systems and their respective implementation status, there is a much higher risk of delay in Galileo than in EGNOS.

3.3.2 Aircraft perspective

The cost of meeting the aircraft requirements predominates in the overall cost of implementing the navigation element of the CNS/ATM concept. Costs of transition to new navigation systems and concepts are mainly driven by the airborne installation costs and sometimes operational benefits are lower than installation/certification costs. In considering the costs and benefits to be derived, a major problem in all the implementations undertaken or planned in the ECAC area is the difficulty of supporting existing capabilities whilst providing a cost effective transition to the future system. The timing of required airborne system changes and the ability to provide early operational advantages from equipage are critical to the cost effectiveness of any change.

It is foreseen that avionics/receivers manufacturers will develop multiconstellation user receivers capable of combining signals from different constellations and augmentation systems (e.g. ABAS, GBAS and SBAS) to provide positioning data and timing data for navigation applications. 3 types of ABAS systems can be considered: RAIM (Receiver Autonomous Integrity Monitoring), Integrity monitoring based on cross-checking with other on board navigation means and inertial coupling. It has to be recognised that no single avionics package fits all airspace users as there is a wide range of aircraft types. For example, large commercial aircraft are normally equipped with precision inertial systems that other users (e.g. GA, regional airlines and business jets) can not normally afford.

It is foreseen that in some years, all new GPS receivers will be SBAS compatible receivers, that INS systems will become more affordable and all new aircraft will include multi GNSS receivers before 2017. It is assumed that all new large aircraft will be equipped with GBAS with a minimal forward fit cost. In some aircraft the GBAS CATI capability is already offered as optional equipment, and some new aircraft will have GBAS as standard equipment.

Being GNSS a key navigation component of SESAR, it is expected that a multi-constellation GNSS receiver (including aircraft, space, or ground based augmentations as appropriate) will be included within the ‘SESAR avionics package’.

The complexity of the mult constellation receiver, the definition of the most efficient combination of signals and the scalability aspects (e.g. to reduce forwards fit costs when new GNSS signals become available) will have to be addressed in coordination with appropriate standardisation groups (e.g. EUROCAE WG 62).

EASA documents (e.g. ETSO, AMC 20) for the different type of applications need to be issued timely to allow the airworthiness certification and operational approval.
3.3.3 ANSPs perspective

Development of new operations based on GNSS relies on the provision by ANSPs of safety cases compliant with ESARR 4 regulation, which will have to be approved by National Supervisory Authorities. This process is based on the development of different enablers by the ASNPs, inter-alia:

- Provision of NOTAMS
- Legal recording of the different signals used
- Design of procedures and publication in the AIP
- Development of new ATC procedures
- Flight inspection
- Training to Air Traffic Controllers

EUROCONTROL is providing support to ANSPs and harmonising activities at European level in this field.

3.4 ECONOMIC ASPECTS: CHARGING POLICY FOR EGNOS AND GALILEO

3.4.1 Background

In line with the SESAR political objectives, GNSS shall contribute to increase the overall cost-efficiency of navigation in the long term. GNSS should support to reduce the current cost-base of the navigation infrastructure, even if this amount is a marginal part of the total ATM costs.

The aviation sector is highly sensitive to economic factors and business decisions are “benefit driven” rather than “technology driven”. Aircraft operators chose the navigation equipment to meet the required safety and operational requirements, based on economic arguments: comparing operational benefits of each alternative with their associated costs (e.g. on board-installation, certification). Additionally there are costs to the ANSPs related to the introduction of GNSS based operations (e.g. procedures, training, flight inspection, ...).

The EC and the GSA have indicated that a service fee could be levied for the EGNOS and the Galileo SoL services to the ANSPs based on market conditions, without giving details on the service provision scheme and the pricing policy that is intended to be applied to aviation.

The present lack of a positive cost benefit analysis for the overall community, and the fact that there is the declared intention to charge aviation, are two fundamental reasons for the negative perception of the EGNOS and Galileo SoL services by many airspace users. Not having a clear, fair and non-discriminatory GNSS pricing policy from the EU for aviation is introducing uncertainties in the business cases of both ANSPs and airspace users, and is therefore detrimental for the operational introduction of these services in aviation. As already identified in the SESAR definition phase, this subject should be clarified as a matter of urgency, in particular for EGNOS.

Even if there are still many uncertainties around the charging policy on GNSS in Europe, this section aims at setting the scene and formulating some conclusions on this sensitive issue.

3.4.2 Value of the services.

The EGNOS and the Galileo SoL services have been defined as comprising a signal in space offering a level of performance, and a certain level of service guarantees. Before discussing any charging policy, the value of these services has to be determined, considering the capability of the signals to provide operational benefits to different airspace users, and the value of the service guarantees offered compared with alternative schemes (e.g. inclusion of EGNOS within current ANSP insurances). In any case, charges have to be commensurate with benefits.
3.4.3 Fairness between user communities.

GNSS systems are multimodal and non-encrypted signals are available to users from different communities offering, with the adequate receiver, the same level of performance to all of them. Users from all communities will benefit from the performance level required by the aviation safety standards and it would be unfair and discriminatory if the aviation community were to be the only one paying, whereas there are users from other communities, using the same signals with the same performance for free for commercial (e.g. farmers, insurance companies, fleet management,..) or transport applications (e.g. rail, road transport charging systems, road transport navigation, maritime..) that sometimes are competing with air transport applications.

3.4.4 Fairness inside the aviation community.

The EUROCONTROL Central Route Charges Office is an efficient cost recovery system that funds en route air navigation facilities and services. The CRCO is charging airspace users on the basis of the availability of services and not on the actual use of the services. In the case of EGNOS, users that can potentially benefit more from the use of EGNOS (e.g. General aviation, helicopters, Business jets,...) are the ones who pay less to the CRCO system, whereas the airlines that don’t plan to invest in equipping their aircraft with EGNOS are the ones that would be negatively affected by the introduction of EGNOS related costs in the CRCO system.

3.4.5 The ICAO policy on cost allocation

The ICAO policy on GNSS cost allocation concludes that basic GNSS services (e.g. GPS, Galileo OS) will be provided free of charge, whereas the incremental costs for more advanced GNSS services (e.g. integrity) should be allocated in a fair manner between all communities of users (e.g. maritime, road, aviation, agriculture,...), which can derive benefits from them. When allocating costs to aviation it has to be considered that the amount has to be commensurate with the benefits and always considering civil aviation’s willingness to pay.

Moreover, based on the principle of not augmenting total cost-base related to navigation services, the total cost-base composed of ground based navails and GNSS should remain constant or be increased by less than the operational efficiency gains (e.g. derived from provision of vertical guided approaches in non-ILS runways).

3.4.6 Charging: the market approach scheme

According to this scheme, the service provider/s in charge of EGNOS and the Galileo SoL service would offer a service ( signal+ a service guarantee) to ANSPs that would have the freedom to purchase or not. This commercial relation would be formalised by means of a contract and the service fee would be negotiated according to the value of the service and the price of alternative solutions. The ANSPs would recover these costs as the other ATM related costs according recognised rules and procedures.

In this case, it has to be considered that, If there are no significant operational benefits that can be exclusively obtained today or in the foreseeable future from a service for which a fee will be charged, ANSPs/users will choose other technology or GNSS solution (e.g. ABAS based on inertial systems, Open services augmented by RAIM functionality, Baro VNAV,...) that are free of charge.

In this scheme, the adequate regulation should be put in place to prevent the potential abuse of a dominant position in the market.

3.4.7 Conclusions on the charging policy for EGNOS and GALILEO

Considering that there are no signs of the establishment of a charging mechanism for non-encrypted signals in the non-aviation communities; it is very unlikely that a pricing scheme, based on either a market or a cost allocation/recovery approach, could be designed and implemented, which would respect fairness and non-discrimination principles. Additionally, any charging mechanism has to be cost efficient to prevent that the costs related to the charging mechanism and its enforcement could be higher that the potential revenues that could be generated.
It would be unreasonable that systems owned by the European public sector are exploited in a discriminatory manner under the pretext of applying market rules because it is not practical to charge other communities of beneficiary users. Even if some ANSPs or airspace users would be willing to pay a fee for a GNSS service according to market conditions, it would be unfair that other communities could make an opportunist use of the same level of performance without paying for them. Such situation would occur simply because the expected market conditions would not be there, and it could in fact distort competition.

The provision of GNSS integrity services (e.g. EGNOS or Galileo SoL) will increase the overall GNSS performance and robustness and can provide some operational benefits to some stakeholders but not to the extent of the aviation community being collectively willing to pay for them, whilst moreover being discriminated against with respect to others.

Therefore, if there is no practical and cost effective way of implementing a fair charging scheme, between all user communities as well as inside aviation, based on either a cost allocation/recovery or on a market approach, EGNOS and Galileo SoL services should be provided for free to aviation as public utilities. Significant indirect benefits from aviation to the society will be generated: safety benefits (e.g. fewer accidents), environmental benefits (e.g. reduction of noise impact and fuel consumption) and macroeconomic benefits. A public utility approach for GNSS services to aviation would facilitate to reduce navigation costs in the long term, in line with the political objectives of SESAR.

3.5 CERTIFICATION AND LEGAL ASPECTS

The certification process and the establishment of an adequate legal framework would allow further reliance on GNSS and would alleviate some institutional concerns due to the international dimension of GNSS and the lack of direct control over the GNSS infrastructure.

It is foreseen that European GNSS systems and service providers will be subject of a certification process based on the four Single European Sky (SES) regulations:

- The Framework Regulation (Regulation No. 549/2004)
- Common Requirements for the Provision of Air Navigation Services (Regulation No. 2096/2005)

The combined use of signals from different constellations will allow a progressive reliance on GNSS and therefore is the essential element of this GNSS Policy. Signals from GNSS constellations that are owned and operated by non-European entities (e.g. GPS or GLONASS) will be combined with signals from GNSS systems under European control (i.e. EGNOS and Galileo) and GBAS stations. It is not foreseen the use of Galileo signals alone in aviation. The SES regulations can not be applied to GNSS systems owned and operated by non-European and military entities.

The notification of the governments of the US and the Russia Federation to ICAO on the availability of the signals coming from GPS and GLONASS to civil aviation was the basis for the inclusion of the signals coming from these systems into the ICAO SARPS. It is expected that the EU will make to ICAO a similar statement related to Galileo in due time.

The adequate safety assessments will determine the conditions upon which the use of signals coming from these constellations for aviation applications in ECAC will be allowed. A waiver on the application of the SES regulations to non-European GNSS systems should be accepted by the Single Sky Committee or relevant National Supervisory Authorities.

Regarding the management of GNSS liabilities at institutional level, it has to be highlighted that this issue must be addressed urgently. EUROCONTROL, in coordination with the European Commission and ECAC Member States, has proposed to ICAO the implementation of a contractual framework as a step forward towards a convention in the long term. This framework has to be implemented for EGNOS before entering into its operational phase by means of the necessary agreements/contracts between the concerned parties (e.g. European GNSS Supervisory Authority, EGNOS Service Provider, NSAs).
<table>
<thead>
<tr>
<th>Acronyms</th>
<th>Description</th>
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<tbody>
<tr>
<td>ABAS</td>
<td>Aircraft Based Augmentation System</td>
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<tr>
<td>ADS-B</td>
<td>Automatic Dependent Surveillance Broadcast</td>
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<td>AIP</td>
<td>Aeronautical Information Publication</td>
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<td>ANSPs</td>
<td>Air Navigation Service Providers</td>
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<td>APV</td>
<td>Approach with Vertical Guidance</td>
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<tr>
<td>A-SMGCS</td>
<td>Advanced - Surface Movement Guidance and Control System</td>
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<tr>
<td>BaroVNAV</td>
<td>Barometric Vertical Navigation</td>
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<td>B-RNAV</td>
<td>Basic Area Navigation</td>
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<td>DH</td>
<td>Decision Height</td>
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<td>DME</td>
<td>Distance Measurement Equipment</td>
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<td>EGNOS</td>
<td>European Geostationary Navigation Overlay System</td>
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<td>GBAS</td>
<td>Ground Based Augmentation System</td>
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<tr>
<td>GNSS</td>
<td>Global Navigation Satellite System</td>
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<td>GPS</td>
<td>Global Positioning System</td>
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<td>ILS</td>
<td>Instrumental Landing System</td>
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<tr>
<td>LPV</td>
<td>Localizer Performance with Vertical Guidance</td>
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<tr>
<td>MEO</td>
<td>Medium Earth Orbit</td>
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<tr>
<td>MRD</td>
<td>Mission Requirements Document</td>
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<tr>
<td>NPA</td>
<td>Non Precision Approach</td>
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<tr>
<td>PBN</td>
<td>Performance Based Navigation</td>
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<tr>
<td>P-RNAV</td>
<td>Precision Area Navigation</td>
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<tr>
<td>RAIM</td>
<td>Receiver Autonomous Integrity Monitoring</td>
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<td>RNAV</td>
<td>Area Navigation</td>
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<td>RNP</td>
<td>Required Navigation Performance</td>
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<td>SBAS</td>
<td>Satellite Based Augmentation System</td>
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<tr>
<td>SESAR</td>
<td>Single European Sky Advanced Research</td>
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<tr>
<td>SoL</td>
<td>Safety Of Life</td>
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<tr>
<td>TMA</td>
<td>Terminal Area</td>
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<tr>
<td>WAAS</td>
<td>Wide Area Augmentation System</td>
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