Provision of emergency communication messages through SBAS: The ESA ALIVE concept

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ABSTRACT

The European Tripartite Group, (ESA – EC – EUROCONTROL) has implemented, via the EGNOS project, the European contribution to the first generation of Global Navigation Satellite System (GNSS-1). The European Space Agency (ESA) has been in charge of the system design, development and qualification of an Advanced Operational Capability (AOC) of the EGNOS system (also known as EGNOS V1).

In summer 2005, EGNOS has reached two major program milestones through the formal technical qualification process (known as ORR, Operational Readiness Review) and the start of its initial operations. These two events mark a successful completion of more than 8 years of intensive work by ESA and European industry.

In parallel to the start of EGNOS operations, EGNOS is planning a modernization plan to cope with GPS modernization, service extension, standard evolutions and the anticipation of some future Galileo missions. In this context, the availability of free bandwidth enables systems like EGNOS to broadcast additional communication messages. These messages could be, the broadcast of

- Warnings or instructions on the occurrence of natural disasters, calamities, dangers for the safety of life within areas with poor telecommunication infrastructure
- Search and Rescue Return Link Messages.
- Warnings or instructions on limitations in the use of SBAS for specific applications (e.g. aviation)
- Other uses.

We refer to these, in general, as the Communication Function of EGNOS. Of these, this paper will focus mainly on the first two, with two concrete proposals: the ESA ALIVE Concept, (Alert interface via EGNOS) and the SAR Return Link. The authors consider the ESA ALIVE and the SAR return link proposals as meaningful and viable concepts, which may be implemented in a reasonable short time frame, contributing to save lives in the event of disasters.

INTRODUCTION

Disaster prevention and mitigation is a subject to which currently intensive attention is devoted. One of the main goals is to identify ways to inform people at risk, for instance, through natural events such as earthquakes, tsunamis, hurricanes, storm surges, extreme precipitation and flooding, or volcanic eruptions, so that specific actions can be taken to mitigate the impact of the disaster and ultimately, to save lives. Moreover, the same information channels would be valuable tools to support rescue and aid operations in the aftermath of disasters thus reducing the total loss of human lives. This discussion is motivated by the obvious principle that ***disaster prevention, mitigation and preparedness are better than mere disaster response.***

Those most affected by disasters are often the poor and the socially disadvantaged in developing countries as they are the least equipped to cope with the situation. In large regions of the Earth, loss of life and capital caused by disasters is increased by the lack of sufficient communication infrastructure for warning, preparation and rescue. For instance, in African countries and the Indian Ocean, where the lack of communication is a severe limitation for efficient warning systems, additional communication paired with a positioning service could be of great help.

The COSPAS-SARSAT Search and Rescue system has helped save many lives during the past several years. This is currently a one way communication system where the distress beacon sends information to the rescue coordination centres. There is no way of communicating the acknowledgements or other rescue related information back to the distress beacon. Having this added functionality will definitely help in improving the efficiency of the Search and Rescue system, resulting in saving a lot more lives. This functionality is currently planned in Galileo.

In both these and other similar contexts, the possibility to use Satellite Based Augmentation Systems (SBAS) message broadcast capability is of considerable interest. Indeed, SBAS systems (EGNOS, for the case of Europe) are associated with a number of inherent characteristics, which make the SBAS solution very attractive:

- The three existing SBAS together provide a global GEO broadcast coverage;
- SBAS receivers are based on GPS receivers and share the same worldwide accepted standards; we may consider that GPS/SBAS is the most popular "satellite communication" (meaning able to receive communication information through satellite) receiver worldwide;
- SBAS GPS receivers can combine the possibility of warning with the ability to determine the location of the receiver in the same equipment (key feature);
- The SBAS systems, having been conceived as safety of life systems with integrity, include the necessary built-in features to guarantee adequate message broadcast, integrity of messages, confirmation of transmission; acknowledge messages to sending organisations, etc;
- It is estimated that there is enough transmission Bandwidth (BW) available to accommodate the proposed function;

SBAS are institutionally controlled, do include security features and are operated for safety of life (i.e. all days all hours of the year with Safety of Life operational standards).

DISASTER ALERTING MISSION

The term "disaster" denotes intense perturbation of people, goods, services and environment, due to natural causes or generated by human being, which exceed the reaction capacity of the affected community. Disasters can be classified as:

- Natural disasters;
- Biological disasters;
- Technological disasters.

Disasters due to **natural** environmental forces can be classified as follows:

- **Disasters generated by dynamic processes in the Earth**, including, for instance; earthquakes, tsunamis or volcanic eruptions.
- **Disasters generated by dynamic processes on the Earth's surface,** including, for instance, land slides, rock avalanches, subsidence and collapses.
- **Disasters generated by meteorological or hydrological phenomena,** including, for instance, storm surges, inundation, extreme frost and snow fall, storms, hailstorms, tornadoes, hurricanes, and wild fires.

Disasters of Biological nature also exist such as plagues or epidemics.

Finally, **disasters of Technological nature** encompass fire, explosions, chemical substance spills, environmental contamination, wars, subversion, and terrorism.

Obviously, the ALIVE mission will not necessarily focus on all types of calamities listed above. A detailed mission assessment will be necessary as a first step, identifying (at least):

- The available observation and sensing elements for each kind of disaster, principally focusing on existing professional world-wide networks.
- The kind of information that, derived from observation and information systems, can be timely provided to end users to avoid personal damage and save lives.
- The reaction time requirements.
- The added value of the position information.
- The associated information mission requirements (necessary BW; time to send; acknowledgement mechanisms; format; etc.).
- The potential recipients of the messages.
- Other available communication information means.

In general terms, the ALIVE system shall be able to:

- Sense primary variables relevant to inform (general people and governmental/local authorities) on the kind and severity of a risk for a disaster prior to the event, the precise location area of concern, as well as to provide information for their mitigation in real-time;
- Provide complementary information that can help saving human lives, such as the necessary action recommended to be taken;
- Broadcast this information through SBAS systems, via Geostationary satellites, with a global coverage. In the case of EGNOS, this information can also be broadcast through other means thanks to the EDAS (EGNOS Data Access System) dissemination system.

SEARCH AND RESCUE RETURN LINK MISSION

The detection and location of an aircraft crash or maritime distress is of paramount importance to the Search and Rescue (SAR) teams and to the potential survivors. Studies show that while the initial survivors of an aircraft crash have less than a 10% chance of survival if rescue is delayed beyond two days, the survival rate is over 60% if the rescue can be accomplished within eight hours. Similar urgency applies in maritime distress situations, particularly where injuries have occurred. Furthermore, accurate location of the distress can significantly reduce both SAR costs and the exposure of rescue forces to hazardous conditions, and clearly improve efficiency. In view of this, Canada, France, Russia and the USA established the Cospas-Sarsat satellite system to reduce the time required to detect and locate SAR events world-wide.

Cospas-Sarsat is a satellite system designed to provide distress alert and location data to assist search and rescue operations, using spacecraft and ground facilities to detect and locate the signals of distress beacons operating on 406 Megahertz (MHz) or 121.5 MHz. The position of the distress and other related information is forwarded by the responsible Cospas – Sarsat Mission Control Centre (MCC) to the appropriate national SAR authorities. Its objective is to support all organizations in the world with responsibility for Search and Rescue operations, whether at sea, in the air, or on land.

One of the new developments of the Search and Rescue system is to provide a return link to the distress beacon [5]. The return link message can contain information like;

- Distress Alert was received by the SAR Local User Terminal.
- Distress Alert reached Rescue Coordination Centre
- Help is on the way
- Any other relevant information.

This return link message will comfort the user in distress and also ensures that the user reduces the alert rate transmission, thereby saving a significant amount of bandwidth. This will also facilitate the rescue operations and help in identifying and rejecting the false alerts. This service is already planned to be implemented as part of the GALILEO development. In this paper we assess the possibility to anticipate this functionality as part of the SBAS system, assessed, specifically, for the case of EGNOS.

THE EGNOS COMMUNICATION FUNCTION CONCEPT

Available EGNOS Bandwidth

In this section we briefly provide some information on the current estimated available BW for additional EGNOS messages. This analysis is based on the RTCA DO229C MOPS standards [6], which define the minimum update rate that needs to be respected by EGNOS to comply with the safety of life requirements.

Table 1 lists all current EGNOS broadcast messages and the minimum necessary BW to comply with the International Standards. In this table, we have assumed that MT0 (which is today sent every 6 seconds) is removed (as it will be the case when transmitting Safety of Life messages early in 2007) or combined with MT2 – MT0/2 (as planned to be implemented early 2006).

This analysis reveals that assuming GPS safety of life transmission the BW available for additional messages will be of the order of 35% of the total BW, i.e. equivalent to 75 bps. Since the transmission of EGNOS messages is made in block messages of 250 bits, this opens up for the transmission of about 1 message, of 250 bits per second, each 3–4 seconds. Part of this extra BW could well be used to provide the EGNOS communication messages like the SAR return link messages or the information on disaster management through the ALIVE interface.

Concerning SAR return link, it is of interest to note that a preliminary mission analysis based on Galileo revealed that the bandwidth required to fulfil the mission requirements was 3.33% (7bps) i.e. an EGNOS message is sent every 30 seconds (thus only consuming about 1/10 of the total available extra BW). The ALIVE mission, being a service of similar nature, is believed (though this needs to be confirmed by the relevant disaster management experts) to require a bandwidth in the same order of magnitude. Therefore, the ALIVE mission is considered to be fully compatible with EGNOS existing margins. Moreover, the excess bandwidth can be used for other EGNOS message broadcasting services, such as for EGNOS extensions, or other communications functions or specific information to aviation users on interferences (RFI) or similar.

Table 1: EGNOS Message BW Utilization, with the MOPS specified update rates with MT0/2 (or no MT0)

Message Type	Maximum Update Interval	Number of Messages Transmitted over ECAC	% BW required over ECAC
MT 0	6	0	0
MT 1	120	1	0.83
MT 2 or MT0/2	6	1	16.67
MT 3	6	1	16.67
MT 4	6	0	0.00
MT 5	6	0	0.00
MT 6	6	0	0.00
MT 7	120	1	0.83
MT 9	120	1	0.83
MT 10	120	1	0.83
MT 12	300	1	0.33
MT 17	300	1	0.33
MT 18	300	4	1.33
MT 24	6	1	16.67
MT 25	120	4	3.33
MT 26	300	18	6.00
Free BW			**35.34 (75bps)**

It is also worth to note that the available EGNOS BW may still be higher, if the fact that the GPS Selective Availability (SA) has been removed in May 2000 is taken into account. Indeed, actual DO229C standards do allow the relaxation of the update of the fast clock corrections from the 6 seconds to be used in the case of SA activated (which is the current adopted baseline in EGNOS) to up to 60 seconds when SA is off (which is the current situation). Table 2 shows the equivalent available extra BW for EGNOS for the case of SA off, which reaches a value of 63% (equivalent to 140 bps). Thus, approximately one extra EGNOS message of 250 bps could be sent every 2 seconds for extra services, such as SAR return link and ALIVE. This is believed to be a very comfortable BW for these kinds of services.

Table 2: EGNOS Message Bandwidth Utilization, with the update intervals of fast corrections of 60 seconds

Message Type	Maximum Update Interval	Number of Messages Transmitted over ECAC	% BW required over ECAC
MT 0	6	0	0
MT 1	120	1	0.83
MT 2 or MT 0/2	60	1	1.67
MT 3	60	1	1.67
MT 4	60	0	0.00
MT 5	60	0	0.00
MT 6	6	1	16.67
MT 7	120	1	0.83
MT 9	120	1	0.83
MT 10	120	1	0.83
MT 12	300	1	0.33
MT 17	300	1	0.33
MT 18	300	4	1.33
MT 24	60	1	1.67
MT 25	120	4	3.33
MT 26	300	18	6.00
Free BW			**63.68 (140bps)**

Architectural Concept and Preliminary Identification of Operational Interfaces

The broadcast of these communication messages is based on the more general concept of using the available EGNOS BW to broadcast spatially related information from an originator to EGNOS users through dedicated SBAS messages. Fig. 1 indicates the architectural implementation of such communication function embedded within the EGNOS system.

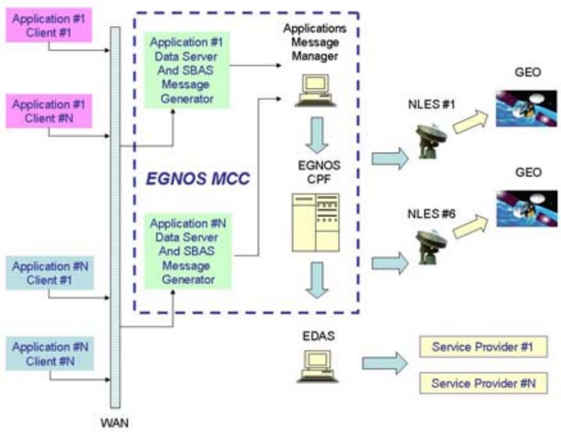

Fig 1: Broadcast of information through EGNOS

Independently from the application considered, the information to transfer to EGNOS users is made available to the EGNOS computing platform (CPF) through links and pre-processing stages. This information is then broadcast as an SBAS message. Users having the possibility to process these specific messages can then extract the enclosed information and use it in the way they need.

The added value of this process is the opportunity to provide reliable information to users equipped with an EGNOS terminal within the entire EGNOS geostationary coverage as indicated in Fig. 2.

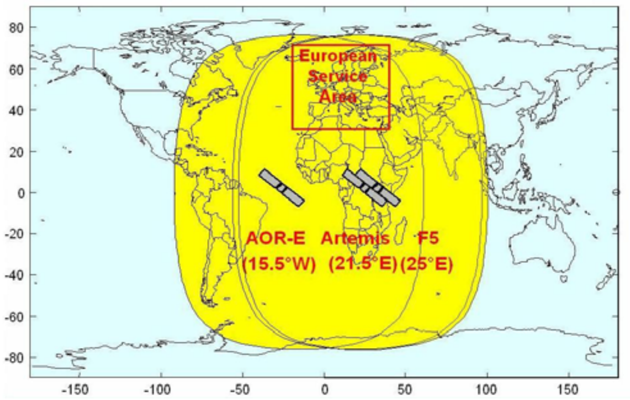

Fig 2: EGNOS Geostationary Satellites coverage

Safety critical information (event, recommended action) is typically associated to spatial information (location). This will be of particular importance for the functions of SAR and ALIVE.

SAR Architectural concept

The EGNOS system shall support the SAR service by providing the return link from the SAR ground segment to the distress beacon. The SAR mission of EGNOS shall have an operational interface at ground segment level with the COSPAS – SARSAT system. The SAR MCC shall send the return link messages to the EGNOS MCC via the Return Link Service Provider. EGNOS broadcasts these in the L1 band, along with the other EGNOS messages. The preliminary conceivable architecture for this service is shown in the following Figure.

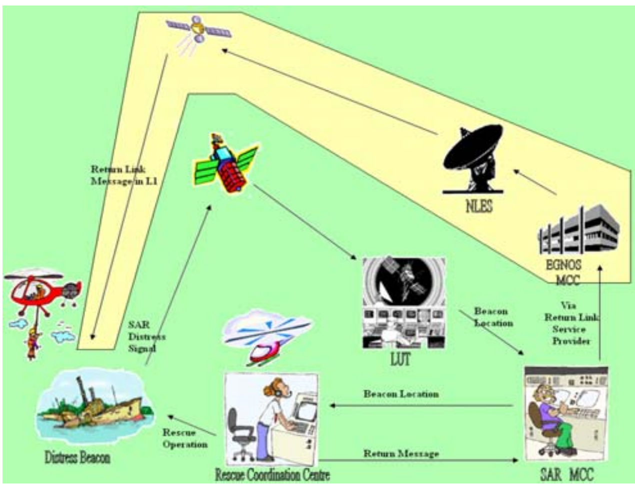

Fig 3: Architectural implementation concept of SAR return link function

The SAR return link service shall be compatible with the low – cost EGNOS receivers, integrated in future advanced beacons.

The Return Link Service Provider is an entity responsible for the organising, formatting and delivering to the EGNOS ground segment the return link messages. The EGNOS ground segment shall encapsulate these return link messages in an EGNOS message and uplink it to its satellites. A dedicated SAR/EGNOS beacon shall be able to receive, display and act upon these Return link Messages.

ALIVE Architectural concept

National and international organisations in charge of disaster management or for the provision of civil protection services make use of infrastructures for monitoring, communication and control. Here we denote such infrastructures as Disaster Management Centres. The architectural implementation of the ALIVE concept on the basis of the EGNOS system is illustrated in Fig. 4.

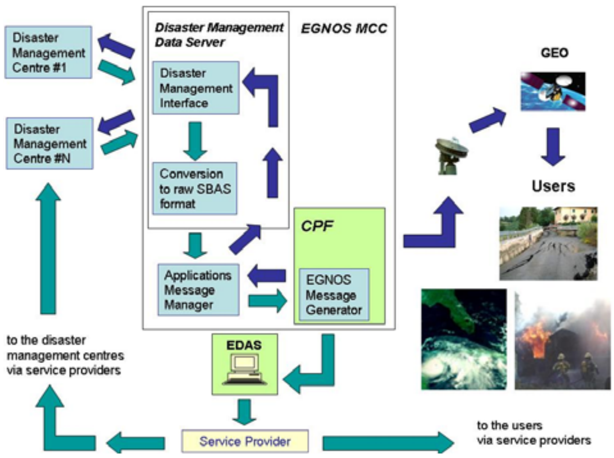

Fig 4: Architectural Implementation of ALIVE function

Disaster Management Centres have the task to collect and generate relevant information (e.g.: event, location, status, action) required to fulfil all the missions for which they have been designed. The information generated by Disaster Management Centres is sent to a dedicated Disaster Management Data Server (Specific Application Data Server) within the EGNOS MCC, which converts this information into raw SBAS format and forwards it to the Applications Message Manager. Disaster Management Centres receive through the Disaster Management Data Server the acknowledgement that the information has been sent with the typical EGNOS guarantee of service.

The Applications Message Manager has the following tasks:

1. to receive the raw SBAS messages from all Applications Data Servers;
2. to put the raw SBAS messages in a preliminary sequence according the mission requirements of each application;
3. to send the SBAS messages to the CPF;
4. to receive the acknowledgement from the CPF that the message has been sent;
5. to return the acknowledgement to the Disaster Management Data Server that the message has been sent.

The EGNOS computing platform (CPF) rearranges the broadcast sequence of the SBAS messages according to the input provided by the Applications Message Manager. The analysis of the preliminary mission requirements of ALIVE revealed that there is no problem to allocate additional SBAS messages among the broadcast of EGNOS current messages.

Once the broadcast sequence is ready, the message (or messages) containing the information generated by the Disaster Management Centres, is included in the EGNOS up-link and down-link loop in the same way as other messages. Any user (within the EGNOS satellites footprint) equipped with an EGNOS receiver capable of processing these additional messages is made aware of the problem, location, status and action. Again, the EGNOS link loop guarantees the delivery of the information to enabled users.

SBAS AN IDEAL SOLUTION TO CONTRIBUTE TO DISATER ALERT AND SEARCH AND RESCUE MISSIONS

The provision of messages through SBAS is considered by the authors as a very adequate solution for disaster management and SAR return link missions. The SBAS systems (EGNOS, for the case of Europe) have a number of inherent characteristics, which make the SBAS solution very attractive in both these cases. This is explained and justified in this Section from different perspectives.

Global coverage

There are currently three SBAS systems available, which will all provide service from 2006 (since 2003 for the case of WAAS): In Europe the EGNOS System developed by the European Space Agency in tri-partite with the European Commission and Eurocontrol, in the United States of America, the WAAS (Wide Are Augmentation System) developed by the Federal Aviation Administration and in Japan the Multi-function Transport Satellite (MTSAT) Augmentation System or MSAS. Other regions are also interested in providing SBAS services although their plans are less advanced than those in Europe, the US and Japan (e.g. India's SBAS, GAGAN, GPS and GEO Augmented Navigation).

The three existing systems (EGNOS, WAAS and MSAS) provide service with a global worldwide coverage, thanks to their complementary SBAS GEO broadcast area footprints. This is illustrated in Fig. 5, where the existing EGNOS, WAAS and MSAS GEO Broadcast areas are just illustrated (note that SBAS L1 broadcast is done through a global GEO beam). The resulting coverage on the Earth is therefore complete with the only exception of the poles. Consequently, when working together, the SBAS systems are a viable way of broadcasting disaster alert/mitigation, SAR Return Link or other similar messages worldwide, for users using the same frequency and signal standards, and therefore fully compatible receivers.

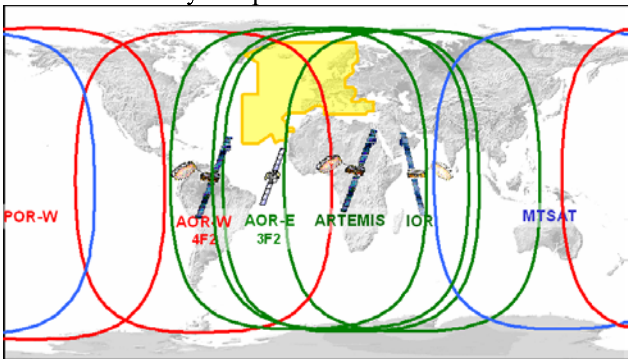

Fig 5: GEO broadcasting areas of the 3 existing operational SBAS

SBAS GPS receivers also provide positioning

Another interesting feature of the SBAS provision for alert management is that in addition to the global coverage provided, the SBAS receiver (needed to demodulate the SBAS disaster alert message) also provides, through their embedded GPS receiver, precise position information. In this way, while a message is sent globally, only those receivers concerned will be activated (e.g. to take a given action or be prepared for rescue). Knowing then the area of the possible disaster location or the beacon ID of the SAR Beacon, the intended users could be warned. Other receivers, providing a position outside the disaster area or with a different beacon ID, would instead be transparent to the call and will not be activated. A possible conception (for the sake of illustration) of the SBAS Alert prevention message is illustrated in Fig 6.

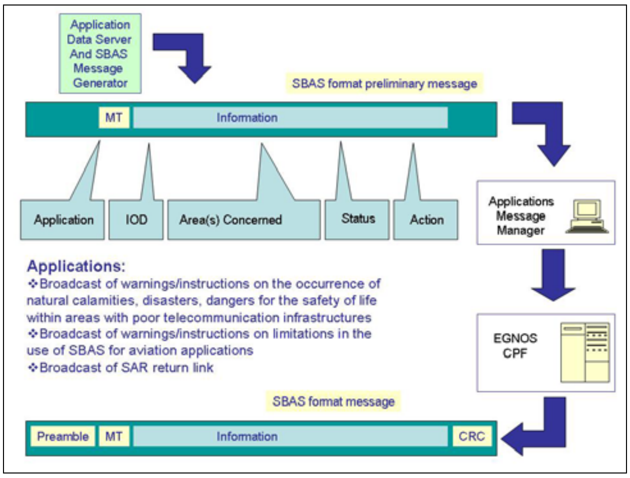

Fig 6: Illustration of a possible SBAS Communication message for alert information

It is to be noted that nowadays, there are a large number of GPS/SBAS receivers available on the market. Indeed, basically, because of the similarity between GPS and the SBAS-GPS-like send signals, almost all developed GPS receivers are also made SBAS compatible receivers. Therefore, the reception worldwide of the SBAS alert message could be easily implemented.

Communication link Available on all circumstances

Either because of poor terrestrial communication infrastructure of the disaster area (which unfortunately is often the case) or because the disaster itself provokes a collapse of the land-based communications, it is of high interest in those cases to have a guaranteed back-up communication link. Satellite communication is the most natural back-up transmission means in those cases. SBAS communication provides a potential satellite communication link, available all the time on the disaster area, irrespectively of the situation of the ground infrastructure. Furthermore, it is to be noted that the most extended worldwide "satellite communication receiver" is the GPS/SBAS receiver, in the sense of a device which is able to receive specific communication data via satellite. No other satellite communication mean is so widely extended.

Unique standard for common receiver

It is also important to note that all the SBAS receivers follow the same international standards, and therefore any SBAS receiver works anywhere in the world in the SBAS coverage area. If a new SBAS message for disaster prevention/mitigation or SAR return link is conceived, this may well be standardised worldwide. This is considered an important feature allowing a global worldwide standardised SBAS alert prevention system and a SBAS SAR return link system.

SBAS provide all guarantees

The SBAS systems, having been conceived as safety of life systems with integrity, include all the following built-in features which are crucial for the considered alert information and SAR return link message, and which are quite unique to SBAS:

- EGNOS has built-in mechanism that guarantees that a message has been sent with the adequate content and on the appropriate time. This information may also be provided back to the alarm or rescue centre interfacing with SBAS.
- SBAS have built-in mechanism to make sure that a message went out in good conditions with no errors.
- SBAS are safety of life systems operated 24 hours a day and 7 days a week (i.e. no service interruptions, in case of failure quick recovery; etc)

Can be implemented in very short term

For the case of EGNOS, the implementation of these interfaces is very well suited to the existing EGNOS architecture. This is believed to be true also for the other SBAS but is unknown to the authors. In the case of EGNOS, the system upgrade to provide the anticipated facility could be done in a short time frame, with low risk and with a simple approach, provided adequate political and institutional support is given. It is believed that this function could be readily available in EGNOS in a timeframe of 2 years after program approval.

Under institutional control

The SBAS systems have all been developed and will all be operated under institutional control. In the case of

EGNOS, the system is currently owned by the European Space Agency member states, and ownership is planned to be transferred to the Galileo Supervisory Authority, a European Institutional Organisation in charge of EGNOS operations and exploitation. WAAS and MSAS are also under institutional control through their respective Governmental Departments for transportation. For the mission intended, having institutional control is considered a key feature since it guarantees service provision, no service interruption, and system necessary future upgrades.

Long system life time when combined with Galileo
Current SBAS systems have been conceived for a typical operation life time of 15 years (i.e. for a time frame around 2020). In addition, there are plans to further modernise SBAS systems and to adapt them to GPS and Galileo modernisation plans. EGNOS is currently integrated in the GALILEO overall strategy, and therefore the complement to this SBAS function through Galileo will also be smoothed and will ensure further long-term duration. This long-term issue is considered a very important feature of the SBAS system with ensures continuity of the proposed ESA ALIVE system.

SUMMARY

Disaster prevention, mitigation and preparedness are better than disaster response. The possibility to use Satellite Based Augmentation Systems (SBAS) message broadcast capability as a means for disaster announcements has been discussed in this paper. Specifically, the implementation of a dedicated interface in EGNOS for disaster alert messages (ALIVE: Alert Interface Via EGNOS for disaster prevention/mitigation) and for the Search&Rescue (SAR) return link messages has been proposed. As explained through this paper, the SBAS systems (such as EGNOS) have a number of inherent characteristics which make the SBAS solution very attractive, including the possibility of global coverage, provision of a combined warning and positioning system, availability of a large number of worldwide common receiver with common standards, SBAS built-in features that guarantee adequate message broadcast (e.g. integrity of message, confirmation of transmission), and the fact that SBAS are operated with safety of life guarantees and under institutional governmental control.

This paper provides a preliminary analysis of the ***mission concept***, the ***interest of a possible SBAS solution*** for these communication functions, as well as an outline of the ***potential architectural concept***; and a ***possible implementation path strategy.***

The authors consider the ESA ALIVE and EGNOS SAR return link proposals as meaningful and viable concepts, which may be implemented in a reasonable short time frame, contributing to save lives in the event of disasters.

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