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# A Proposal for the Extension and Institutional Framework of European Geostationary Navigation Overlay Service (EGNOS) in the implementation of Global Navigation Satellite System (GNSS) in Africa

**[1]J. D. Dodo and [2]T. O. Idowu**
Department of Surveying and Geoinformatics, School of Environmental Sciences,
Federal University of Technology, Yola, Nigeria.
[1]E-Mail: jd.dodo@gmail.com, Phone: +2347059322774,
[2] E-Mail: timothyidowu@ymail.com, Phone: +2348034269273

## Abstract
The Global Navigation Satellite System (GNSS) is a space-based radio positioning system that includes the use of one or more satellite constellations. It was designed for intended operations which include provision of 24-hour geo-spatial positions, velocity and time information to suitably equipped users anywhere on, or near the surface of the earth. The system is at present composed of two operational satellite systems namely: the American Global Positioning System (GPS) and the Russian Global Orbiting Navigation Satellite System (GLONASS). It is expected to include the European Galileo Services in the nearest future. Several augmentation systems designed to provide greater efficiency and accuracy for GNSS users at different levels have been developed and are at various implementation stages. The European Geostationary Navigation Overlay Service (EGNOS) is one of such augmentation systems. Several trials have been conducted in Africa by the European Space Agency (ESA), to ascertain the coverage and performance of EGNOS. The results showed that a satisfactory positional accuracy is achievable in Africa if the process involved is integrated with the European service area, thereby complying with Approach with Vertical Guidance-1 (APV-1). Therefore, this paper proposes EGNOS extension and institutional framework in the implementation of GNSS in Africa and also outlines the benefits to be derived from such implementation. The proposed extension architecture is expected to be an independent solution whereby the processing and uplink of navigation messages will be carried out in Africa with the institutional framework providing the guiding regulations.

**Keywords**: EGNOS Extension, Institutional framework, GNSS implementation and Africa

## Introduction
GNSS technology has gained a worldwide acceptability with promising accessibility, precision, economy as well as sustainability; thereby creating opportunities for local, regional and international technological advances. It is a generic term covering a number of existing and planned constellations of satellites together with supporting infrastructural systems used for determining geo-spatial positions across the globe. They are coordinated with data communications methods such as radio or the Internet which play key role in the operation of integrated information management and control system with diverse range of applications affecting many parts of the national and regional economies. Therefore, the introduction and implementation of satellite navigation technology to the development of the African continent is a right step that

needs to be pursued vigorously. In recognition of the strategic importance of satellite navigation, its potential applications and the need for the African states in joining the rest of the world to enjoy the benefits of the outer space, organizations such as the International Civil Aviation Organization (ICAO), Africa and Indian Ocean (AFI), the Agency for Air Navigation Safety in Africa and Madagascar (ASECNA), the European Space Agency (ESA) and the European Organization for Safety of Air Navigation (EUROCONTROL) have been actively involved in inspirational collaboration to ensure the introduction and implementation of GNSS in Africa.

EGNOS is an acronym for "European Geostationary Navigation Overlay Service". It is a Satellite-Based Augmentation System (SBAS) designed to improve GPS and GLONASS and the soon-coming European Galileo services in terms of accuracy, integrity, availability and continuity. It is being implemented by the European Tripartite Group (ETG) comprising of European Space Agency (ESA), the European Commission (EC) and EUROCONTROL as Europe's contribution to the development of the Global Navigation Satellite System (Com, 2003). EGNOS consists of three (3) geostationary satellites and a complex network of ground stations which, when fully operational, will transmit GPS-like navigation signals which include integrity and differential corrections by the geosynchronous ranging satellites. These corrections are later applied to GPS, GLONASS and EGNOS navigation signals in addition to the signals of other geosynchronous ranging satellites overlay systems for GNSS users within the area of coverage (Rane, and Laurent, 2001). The results of the implementation of this system will lead to greater efficiency, accuracy and hence reliability of geo-spatial positioning in Africa. Therefore, it is the objective of this paper to discuss the possible extension of EGNOS and the necessary institutional framework for the implementation of GNSS in Africa. The benefits to be derived therein are also outlined.

## Justification for EGNOS

The goal of the international community is to achieve an internationally provided, funded, implemented and controlled GNSS. Although GPS and GLONASS are seen to constitute elements of GNSS, they lack the expected accuracy, integrity, availability and continuity that will satisfy many of the more-critical and safety-related applications (Ventura-Traveset et al, 2001). Whereas, EGNOS allows users, in Europe and beyond, to determine their positions within two (2) meters accuracy compared with about (20) meters accuracy for GPS and GLONASS alone (ESA, 2007). Similarly, the dependency on these systems is solely owned and controlled by the military of an individual country. This gives such country the ability to supply or deny satellite navigation signals at any time. That is, the country owner of the satellite signals potentially has the ability to supply, degrade or eliminate satellite navigation services over any territory it desires. This has heightened the concern of the international community in terms of system availability, especially during international crisis. The institutional uncertainty of a single state ownership and control, simultaneous dual military and civil use couple with the technical limitations in terms of accuracy and integrity, censored availability and vulnerability to interference have led to the development of various augmentation systems such as EGNOS in order to meet the requirements of international community for better safety-related applications.

## EGNOS system architecture

EGNOS system consists of the Space segment, Ground segment and User segment as shown in Figure 1.

**Space segment:** The space segment consists of navigation transponders onboard YHM, Inmarsat III Indian Ocean Region (IOR-E) at $64^0.5$ E and ESA ARTEMIS at $21^0.4$ E. They cover not only the whole of Europe but Africa, South America and most part of Asia. It improves the geometry of the GPS constellation by broadcasting GPS-like signal thereby providing integrity and wide area differential corrections (Ventura-Traveset et al, 2001).

**Ground segment:** The Ground segment is made of the Master Control Centres (MCC), Range and Integrity Monitoring Stations (RIMS), Navigation Land Earth Stations (NLES), Wide Area Networks (WAN) and other support facilities.

**User segment:** The User segment is made of EGNOS standard receiver which verifies the Signal-In-Space (SIS) performance and a set of prototype user equipment for the various applications which EGNOS is to provide. These include civil aviation, maritime and land (Rane and Laurent, 2001).

**EGNOS service area**

The EGNOS coverage area includes all European states. Figure 2 shows the European Service area which EGNOS covers. A pre-operational transmission of the EGNOS signals through the EGNOS Test Bed (ESTB) is currently going on in these areas. The EGNOS System Test Bed (ESTB) is the EGNOS prototype which has been broadcasting Signals in Space (SIS) since February 2000. It is meant to support and test the development of the EGNOS system in order to demonstrate its potential to users, to prepare for the introduction of EGNOS and to test the possibility of extending this system outside Europe. The performance of this Test Bed is quite good, achieving accuracy within few meters in providing GPS –augmentation signals for the users to determine their positions (Gauthier et al, 2003).

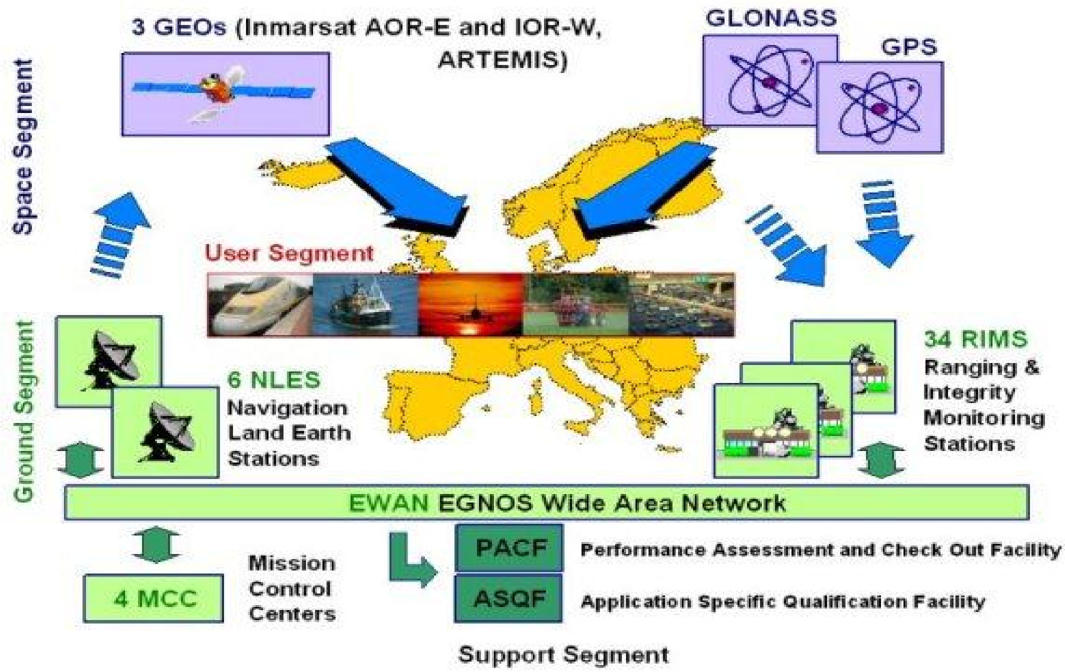


**Figure 1: EGNOS Segments (Gauthier et al, 2003)**

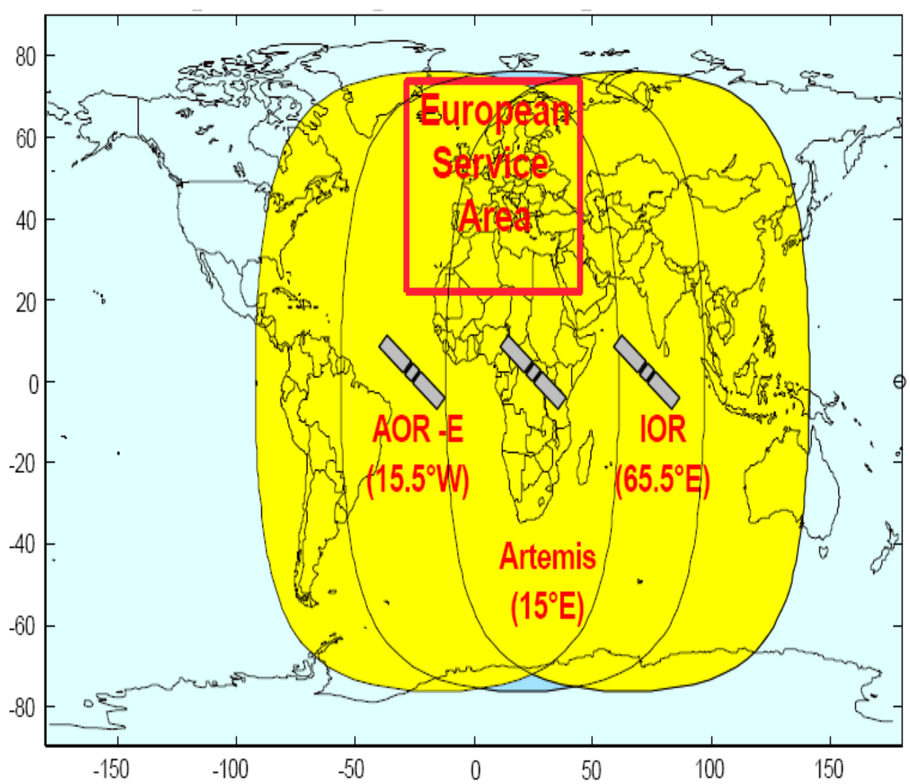


**Figure 2: European EGNOS service area (Gauthier et al, 2003)**

**Existing EGNOS ground infrastructure in Africa**

2Three African sites are included in the EGNOS 34 Range and Integrity Monitoring Stations (RIMS) as part of the EGNOS ground infrastructure. The African sites are shown in Table 1 and Figure 3. They are to be equipped with RIMS channels A, B and C to detect GPS satellite dysfunction and provide raw data to the EGNOS Central Processing Facilities (CPF) in order to carry out differential corrections and integrity monitoring to avoid system failure (Brocard et al, 2000).

**Table 1: EGNOS African Ground Infrastructure (Brocard et al, 2000).**

| Country | Site | RIMS |
|---|---|---|
| Tunisia | Dierba | A, B and C |
| Egypt | Mersa Matrouh | A and B |
| South Africa | Hartebeeshoek | A and B |

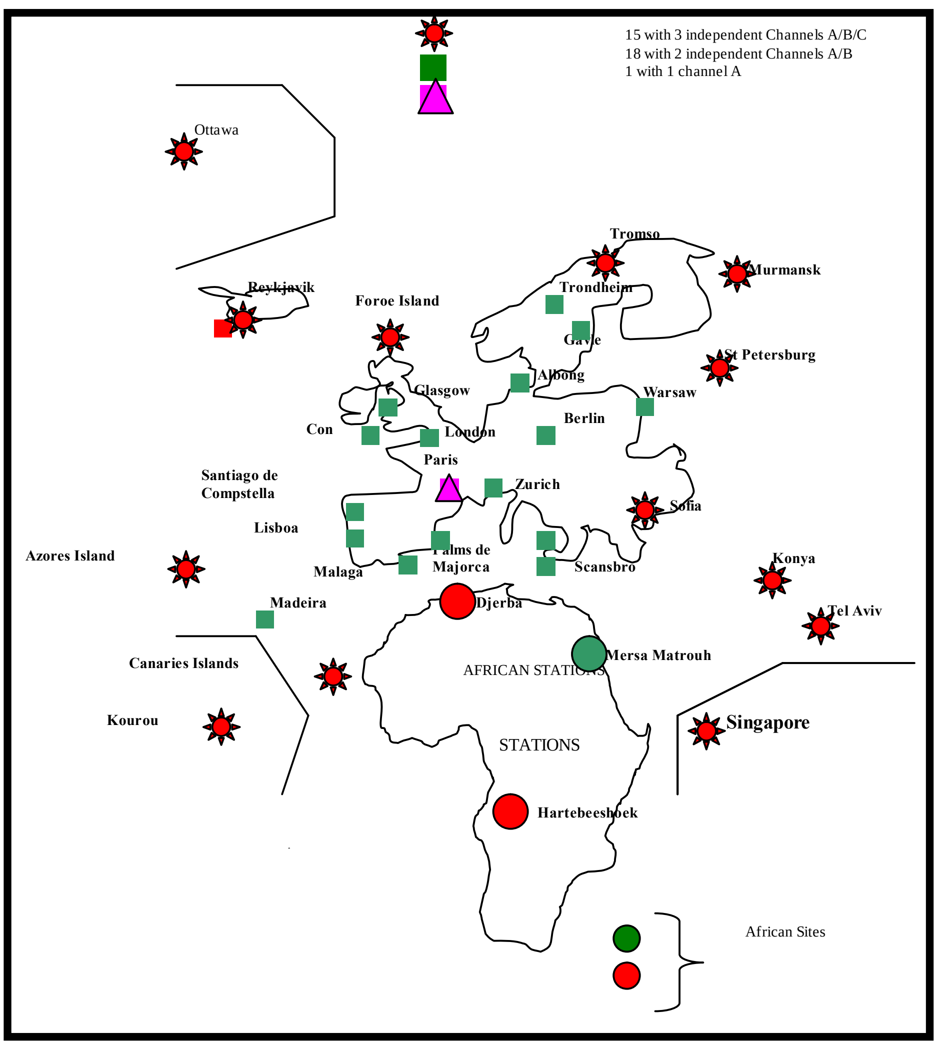

**Figure 3: EGNOS RIMS showing the location of the African sites (Brocard et al, 2000).**

**Table 2: EGNOS Bandwidth usage (Zdzislaw, 2003)**

| Data Type | No. of message instances | Maximum broadcast interval (sec.) | Bandwidth filling |
|---|---|---|---|
| Nominal service area from European Civil Aviation Conference (ECAC) of SBAS in test mode | 0 | 6 | 0.00% |
| PRN mask | 1 | 120 | 0.83% |
| Fast correction GPS | 2 | 6 | 33.33% |
| URDEi | 1 | 6 | 16.67% |
| Long-term corrections | 12 | 120 | 10.00% |
| Geo ranging function data | 1 | 120 | 0.83% |
| Fast correction degradation | 1 | 120 | 0.83% |
| Degradation Parameters | 1 | 120 | 0.83% |
| Ionospheric grid mask | 4 | 300 | 1.33% |
| Ionospheric corrections | 16 | 300 | 5.33% |
| GIVEi Timing data | 1 | 300 | 0.33% |
| Almanac data | 2 | 300 | 0.67% |
| Service level | 1 | 300 | 0.33% |
| TOTAL | | | 71.34% |

## EGNOS extension

The basic concept for the extension of EGNOS outside Europe is the enhancement of navigation performance that can be attainable by the users of EGNOS within the service area. This concept is achieved by transmitting ranging corrections to GPS that are valid to users irrespective of their position. The extension requirements include the following:

**Technical requirement:** One of the fundamental issues in the technical requirement is the ability to properly establish the size of the extension area. This requires analysis of the bandwidth that is available in the geostationary satellites (IMARSART and ARTEMIS). Table 2 provides information on the EGNOS bandwidth usage. About 17 % of the total EGNOS bandwidth has been utilised mainly on the European service area (Zdzislaw, 2003). Therefore, there is the need for an increase in the bandwidth of the geostationary satellites to meet the extension requirements. Other aspect of the technical requirements include proper site observation location of the Range and Integrity Monitoring Stations (RIMS), modification of the current EGNOS Central Processing facilities software to compute the user differential range error, developing ionospheric models that will mitigate the ionospheric effects, a real-time communication network (i. e. Wide Area Network) to allow data transfer to the processing centres and a good data acquisition process that would allow unhindered navigation messages to the Navigation Land Earth Stations (NLES) (Legido, 2001).

**Environmental requirement:** This is the provision of an infrastructure for RIMS indoor equipment to meet up with the indoor environmental requirement. It could be a building having some offices for administrative purposes. Also, there should be an indoor canalisation to allow for separation of power and communication cables in addition to cables made of metal that could cover all indoor interconnection cables. Moreover, considering relatively hot African climate, an air-conditioning system that will provide required temperature should be put in place (Izquierdo et al, 2001).

**On-going EGNOS SIGNAL TEST BED (ESTB) trials in Africa**

Beginning from June 2003, there have been EGNOS mobile trials in Africa, known as EGNOS Signal Test Bed (ESTB). The aim of these trials was to assess the strength of the EGNOS signal with the hope of preparing for the full implementation of the system. Africa is zoned into three, namely: Central Africa as Zone A, Southern Africa as Zone B and Eastern Africa as Zone C (Aline, 2003). Two Inmarsat satellites (AOR-E and IOR-E), which are directly above Africa, are being used for transmission of signal-in-space. Mobile RIMS stations were installed at various locations in each zone. They are equipped with independent Very Small Aperture Terminal (VSAT) for communication purposes. In zone A, the message type MT27 was used in 2003. Though, the accuracy of the results obtained was considered good but the use of Approach with Vertical Guidance -1 (APV-1) which would have improved the accuracy was not available. As a result of this, in February 2004, ESA integrated zone A into the ECAC area, but without the MT27. Sets of 24-hour data were collected every week at Douala, the capital city of Cameroon, RIMS station (Aline, 2003). The procedure of the trials allowed the coverage of continental AFI including Madagascar with the exception of Mauritius and Seychelles. The results of the tests showed that the accuracy achieved was closer to that of Approach with Vertical Guidance -1 (APV-1) having horizontal positional error of about 3m, representing 95% and vertical position error around 4.5 m which is also 95%. More than 98% accuracy was achieved with the Availability of APV-1 service.

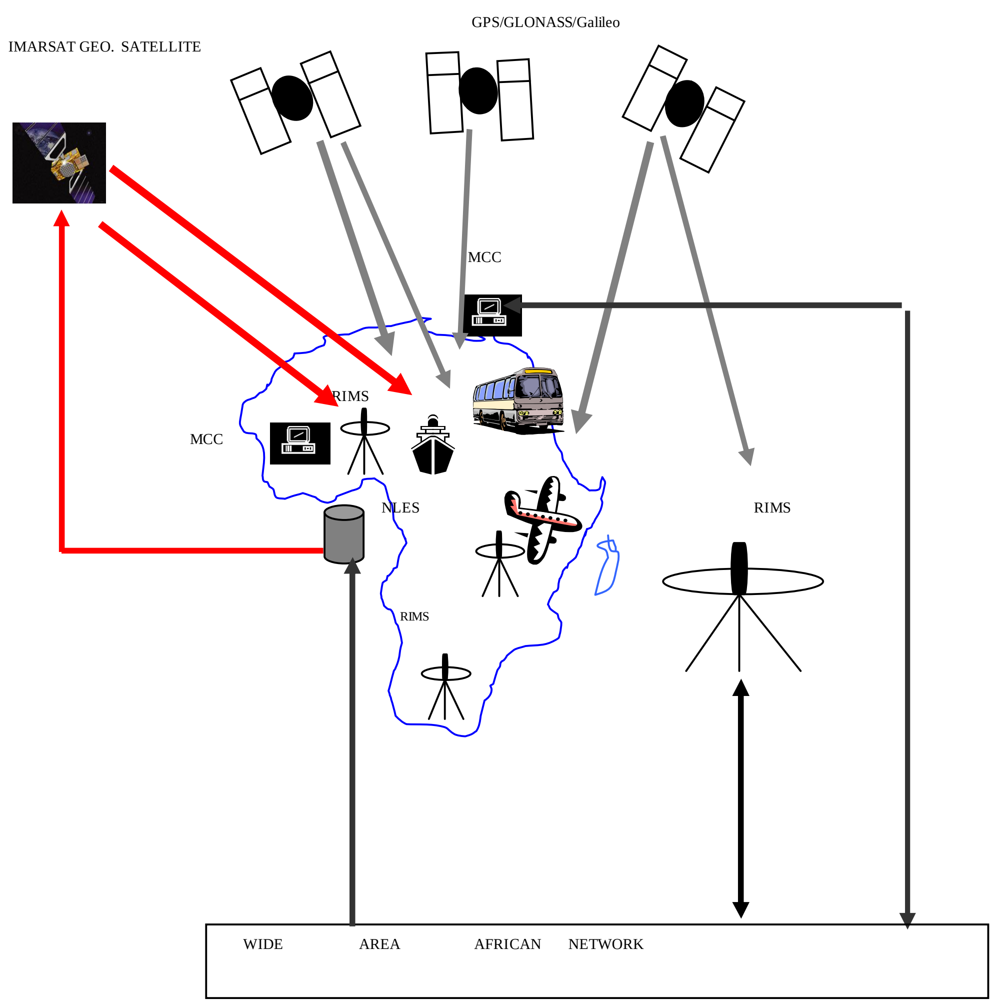

**Figure 4: Proposed Extension Architecture for Africa (Aline, 2003)**

## Proposed EGNOS extension system architecture

This section presents the proposed architecture for EGNOS extension having considered the extension requirements. Figure 4 presents a design of an independent solution where two Monitoring and Control Centres (MCC) with one Navigation Land Earth Station (NLES) for up-link of the message received from the MCC are implemented. The idea is that the African Centres will perform real-time processing of the RIMS data that will allow an on-line monitoring of the African ground infrastructure. The real-time processing includes the computation of the wide area corrections and also the provision of integrity data from those satellites (GPS/GLONASS) that are visible within the African region. Due to its dependency, it would require a dedicated message type MT28 to provide availability and increased integrity inside and outside service area. Therefore, a Wide Area Network (WAN) is required for transmission of messages. The African Monitoring and Control centres could also be linked to one of the European MCC, thus forming a network. The advantage of this design is that there will be provision of enough infrastructures within the African region for GNSS.

## Proposed institutional framework

Considering the final architecture of EGNOS, the need for an international framework to support operation and exchange of information among system designers, operator and international user communities is very important. The framework includes collaboration among the service providers, providing favourable and flexible mechanisms where there will be shared interests in the use of the EGNOS system irrespective of the region of their operation. Such proposed framework for EGNOS extension in Africa is shown in Figure 5.

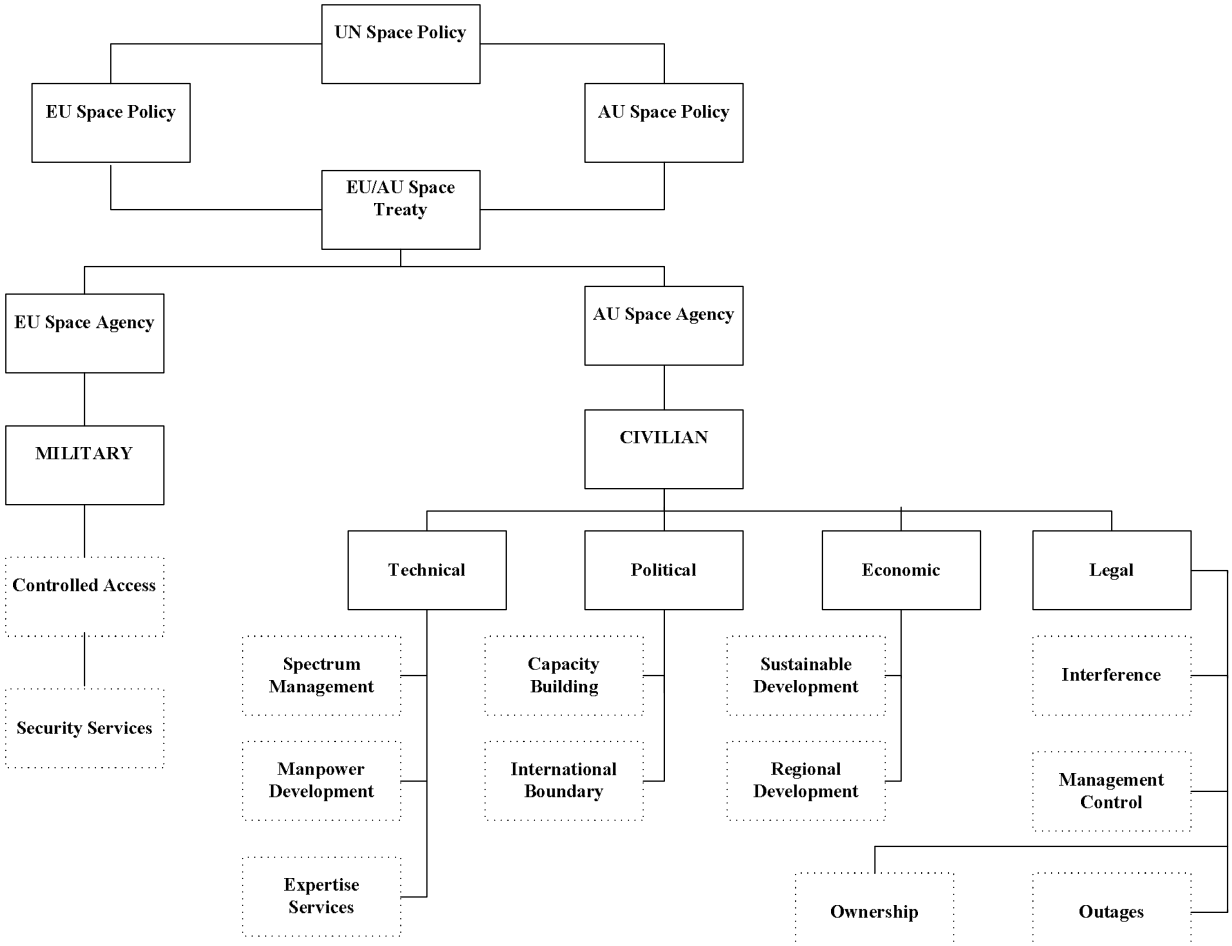


**Figure 5:Proposed EGNOS Institutional Framework**

**Technical cooperation:** The technical cooperation allows the sharing of both expertise and the costs of developing the expertise. This involves conducting joint research and publication of the results. With the extension of EGNOS, there will be sharing of ideas between Europe and Africa researchers in space related research given the diversity of the two continents. It will be of immense advantage to the African scientists given the opportunity to participate in space-related activities that have been previously seemed impossible. The technical cooperation includes, among others, the following:

- Spectrum management
- Man power development
- Cooperation among the service providers
- The provision of expert services.

**Political cooperation:** EGNOS has political advantages that will foster the relationship between Europe and Africa. Such relationship will aid in the management of the airspace of both countries. Europe could support Africa in the area of capacity building as the safety of life services offered by EGNOS will be of much demand by the African States. Therefore, this will facilitate the establishment of EGNOS in completing the first phase of GNSS-1 of the European policy on global navigation satellite system. Also, the extension will facilitate Galileo's market launch in Africa as EGNOS services are precursor to future Galileo's applications.

**Economic motivation:** Regional economic motivation and integration are important factors in fostering relationship. The relationship will strengthen regional economic integration bringing about sustainable development. Lack of or insufficiency of GNSS infrastructure in Africa justifies the urgent need for such cooperation. In addition to the infrastructure deficiency, financial resources mean another specific obstacle for the African States in addition to the technical and political constraints, hence the need for economic cooperation.

**Funding:** Extension of EGNOS to Africa will require heavy investments. Although the cost of the existing GNSS services is free, the provision of EGNOS in Africa would require funding from the stakeholders. The funding cooperation would involve capital outlay for deployment and operational costs which include transmission cost, processing of data and provision of signal-in-space in addition to monitoring and maintenance of equipment. The financial estimate could be worked out after the stake holders have agreed in principle to implement the project.

**Legal framework:** It is important to note that lack of legal framework for GPS has made it impossible for other nations to adopt the use of the basic GNSS. An elaborate legal principle governing the extension of EGNOS to Africa is very essential. Such legal framework should take into consideration the relationship among stakeholders involved in the implementation, operation, provision and use of EGNOS signals. The legal framework should address issues such as unlawful interference with GNSS systems, outages and other legal principles relating to communications by satellite. It should also address the issue of ownership by putting in place a legal ownership concept, management and control of the system. This will foster better understanding and trust between Europe and Africa in an event of system failure and the- likes.

**Benefits of EGNOS to Africa**

The benefits of EGNOS extension and hence GNSS applications are growing in areas including aviation, maritime, land transportation, surveying and mapping, agriculture, power and telecommunications, disaster warning and emergency response. Especially for developing countries, GNSS applications will offer cost-effective solutions to pursue economic growth without compromising the present and future needs to preserve the environment, thus promoting sustainable development.

**Aviation:** African airspace has a disproportionately high rate of accidents associated with the en-route, approach and landing phase of flights which underscores an urgent need for the upgrade infrastructure and implementation of the use of modern technology. Among these shortcomings are poor radar coverage and large number of non-precision approaches. Safety is the key requirement for civil aviation and this demands high level of performance. EGNOS-GNSS will enable gate-to-gate navigation and all-weather operation capabilities for suitably quipped aircraft to provide more precise location of aircraft and hence better landing systems. This will make flying, not only safer, but also more efficient. Also, it will allow for better aircraft separation on more direct routes, reduce en-route and terminal delays and eliminate circling by allowing straight-in approaches to any runway.

**Surveying and mapping:** Surveying and mapping have always been the pioneer of GNSS applications. Using EGNOS-GNSS for surveying and mapping saves time and money with satisfactory positional accuracy. Unfortunately, developments in this area have been very slow in Africa. This is probably due to the fact that different regions use different reference ellipsoids in surveying and mapping. However, there are moves to establish the African Reference Frame (AFREF) which aims at providing a unified spatial reference frame that will provide co-ordinate system which will be consistent with the International Terrestrial Reference Frame (ITRF). This is expected to ensure Spatial Data Infrastructures (SDI) enabled by EGNOS-GNSS (Wannacott, 2006).

**Road/Rail transport:** Vehicle tracking and fleet management system is an application area where practical benefit of GNSS technology can easily be demonstrated and appreciated particularly in Africa where road transport systems has remained the backbone of the mass movement and the haulage industry. The potential large market for the GNSS industry comes from this area of application.

**Agriculture:** The main application of GNSS in the agricultural sector is in precision agriculture. This is due to the need for a more efficient agricultural production practices and environmentally friendly requirements over the traditional farming method. The four main objectives of this technology are to reduce inputs, improve machine control, increase management and field efficiency. Africa will benefit tremendously in this area since most of the continent sources of income lie in agriculture.

**Maritime:** GNSS performance and safety is highly relevant in the maritime environment. Information supplied by GNSS could be used in developing guidance systems for waterways and efficient management of ports operations. With the introduction of Automatic Identification System (AIS) for merchant ships, there will be reliability on information on the ships position and the monitoring of their movement using EGNOS-GNSS. This will solve the problem of vessels declared missing in most of the African ports.

**Management of environment and natural disaster:** The management of environment and natural disaster is a major concern of the entire global community. The environment is the life supporting system for all living organisms including mankind. Its sustainable use is essential for the current and future generations. At the same time, natural disaster continues leading to loss of lives and properties. GNSS has an enormous potential to contribute to the management of environment and natural disaster through the concept of positioning, signal delay and signal reflection amongst other concepts (Carlos, 2003). EGNOS-GNSS can be used in monitoring vessels to reduce oil and dangerous wastes spills caused by marine accidents. Also, it can be used in mapping natural disaster risk zones such as floods, droughts, inland lakes, rivers and disease (e.g. malaria, rift valley fever etc.) prone areas.

## Conclusion

In this paper, EGNOS extension and institutional framework in the implementation of GNSS in Africa are proposed. Also, the benefits to be derived from such proposal are outlined. Therefore, it can be inferred that the immediate and exponential benefits that will be offered by EGNOS-GNSS will result in a safer and more efficient infrastructure.

This will positively influence trade potential and economic viability of African states. In order words, EGNOS-GNSS can truly serve as a catalyst for trade and economic growth of African countries if implemented. Clear government policy, with a national multimodal approach to GNSS related issues, will benefit service providers (both public and private sector), service users and hence African population. Finally, it can be inferred that EGNOS extension in the implementation of GNSS in Africa will constitute one of the most promising space applications that will be of great asset to Africans.

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