

# **Establishment of a Common and Modern African Geodetic Reference System (Afref)**

**Hussein .O. Farah, Nairobi**

## **SUMMARY**

There are almost as many geodetic reference systems in African as there are countries. Sharing of data as is envisaged in Spatial Data Infrastructure (SDI) and seamless map coverage across borders therefore becomes difficult. As we move towards more regional integration and adopt regional approaches to peace and security, environmental management, trade and industry, we need maps that are continuous across national boundaries. Cross border, regional and continental geo-referenced applications, services and products require a uniform geodetic reference system. To solve the problem of lack of such a system in Africa, African Geodetic Reference Frame (AFREF) has therefore been proposed. AFREF is an initiative of United Nations Economic Commission for Africa (UNECA) Committee for Development Information, Science and Technology (CODIST). AFREF is expected to be established using GNSS technology following the standards of the World Geodetic System 1984 (WGS84) and the International Terrestrial Reference Frame (ITRF) Systems. It is proposed that the project be implemented by the all countries in Africa through their National Mapping Agencies with the support of the international community through various scientific and research organizations in geosciences. The objective of the paper is to sensitize and seek a wider support for the AFREF project in the continent and the globe. The objectives, proposed implementation strategy, current status and expected benefits of AFREF will be addressed.

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## **1. INTRODUCTION**

African countries have traditionally maintained their own geodetic reference systems inherited from colonial period resulting in maps in neighboring countries not edge-matching properly at the borders. Apart from increasing the potential for misunderstanding and conflicts, this situation makes it difficult for countries to share information and to work on joint plans and projects. Information on one country's maps could not be easily referenced to that on another country's maps. As we move towards more regional integration, and adopt regional approaches to peace and security, environmental management, trade and industry, we need maps that are continuous across national boundaries. This will be possible through the establishment of a common geodetic reference frame. The concept of a unified geodetic datum for Africa is not entirely new. An effort was made in the 1980s to establish a unified datum using satellite techniques via the African Doppler Survey (ADOS) project. The ADOS project was started in 1982 and was completed in 1986.

The African Geodetic Reference Frame (AFREF) was conceived as a unified geodetic reference frame for Africa to be the fundamental basis for the national and regional 3D reference networks. It is expected to be consistent and homogeneous with the International Terrestrial Reference Frame (ITRF) Standards. ITRF is the global reference frame system for the earth as adopted by the International Association of Geodesy (IAG). When fully implemented, it will consist of a network of permanent Global Navigational Satellite system (GNSS) stations, continuous or otherwise, such that a user any where in Africa would have free access to GNSS data and products, and would be at most 1000 km from such stations. Its full implementation will include a unified vertical datum and shall support efforts to establish a precise African Geoid.

The realization of AFREF has vast potentials for geodesy, mapping, surveying, geo-information, natural hazards mitigation, earth sciences, etc. Its implementation will provide a major springboard for the transfer and enhancement of skills and knowledge in surveying, geodesy and especially Global Navigation Technologies (GNSS) with its applications. along coastal regions.

## **2. OBJECTIVES**

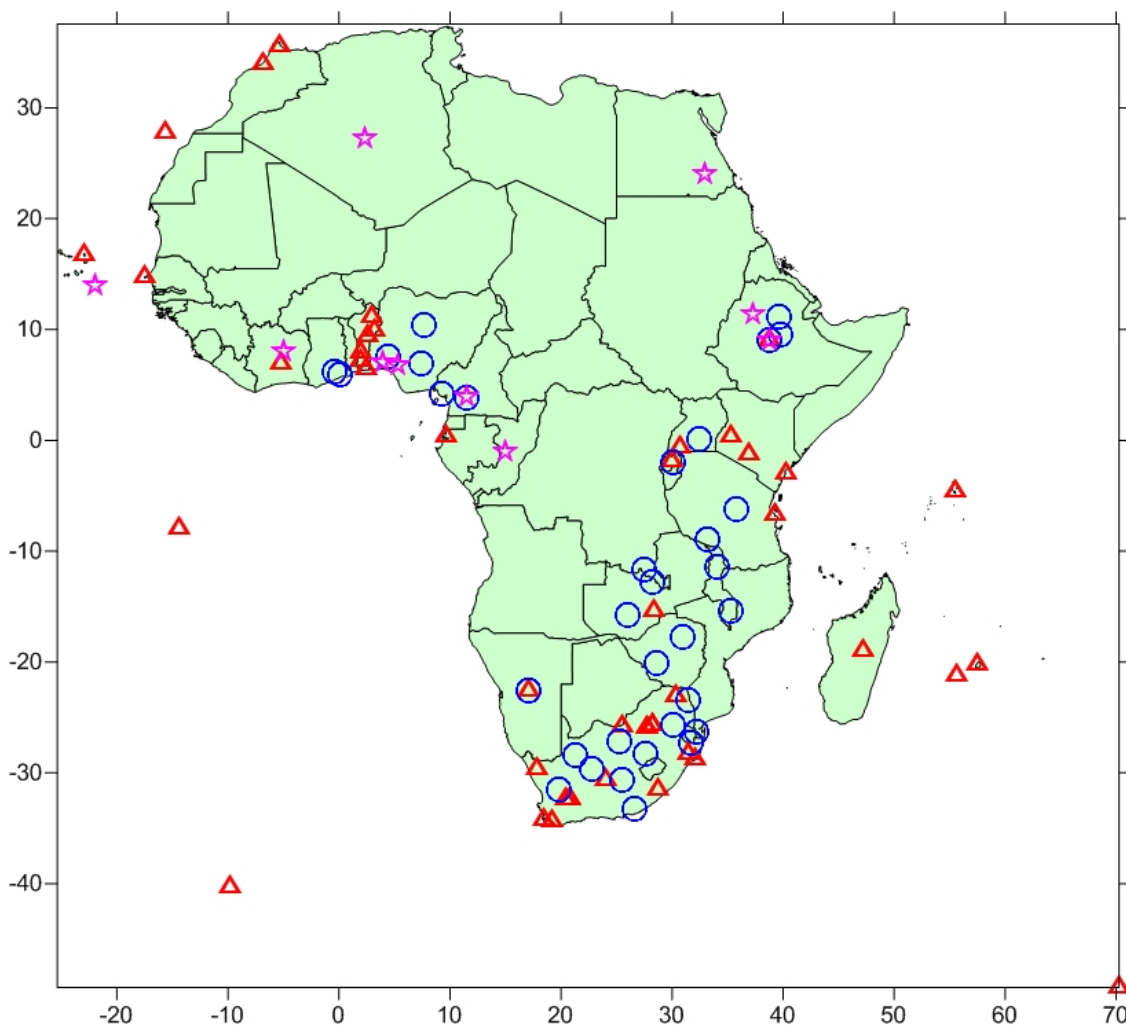
The following are some of the identified objectives of AFREF

- Define a continental geodetic reference frame for Africa
- Establish precise and uniform African geoid
- Establish permanent GNSS base stations such that users have free access to GNSS data and product from such stations

- Provide sustainable development for GNSS and ICT technology transfer within the continent
- Establish an in-country expertise for implementation, operation, management, analysis and presentation GNSS data and products.

### 3. PROPOSED IMPLEMENTATION STRATEGY

International Association of Geodesy (IAG) promotes the concept of unified regional geodetic reference frames all over the world. IAG and its service organizations, in particular the International GNSS Services (IGS) has established a network of continuous GNSS observation stations across the globe. To date more than 200 such stations have been established all over the world since 1992. GNSS data is available free from the IGS web site and its data processing centers. In Africa, approximately 18 (see Figure 1) such stations have been established by various IGS organizations.



**Figure 1: GNSS Network in Africa**

Most of the stations are distributed in the Eastern and Southern Africa and part of Western African coastal region. Central and Northern part of Africa are not covered. Densification of IGS networks with its products in Africa is the first step toward the realization of AFREF. For practical effectiveness, the following implementation and coordination structures have been developed and proposed through various workshops and accepted by Economic Commission of Africa (UN ECA). The proposal is based on continental and regional coordination with national implementation. The following are the proposed implementation regions based on United Nations economic blocks

- NAFREF, North Africa Reference Frame for North Africa comprising of Algeria, Egypt, Libya, Mauritania, Morocco and Tunisia.
- SAFREF, South Africa reference frame for SADAC countries including Botswana Lesotho, Malawi ,South Africa, Swaziland, Namibia, Zambia, Zimbabwe
- EAFREF, East African Reference Frame for IGAD countries including Burundi, Djibouti, Ethiopia, Eritrea, Kenya, Somalia, Rwanda, Tanzania and Uganda
- CAFREF, Central Africa Reference frame (for Central Africa)
- WAFREF, West Africa Reference Frame (for West Africa)

Following the discussions at various forums including the United Nation Economic Commission for Africa (UN ECA) Committee on Development Information Science and Technology (CODIST) meetings, the implementation of AFREF will follow an approach consisting of following three major phases:

- The establishment of a frame work of continuous permanent GNSS base stations throughout the regions that will become part of the worldwide IGS network of stations. These stations must comply with the internationally accepted standards as set out by IGS.
- The densification of the network of permanent base stations, largely on a country-by-country basis, to determine the relationship between the national geodetic system and the ITRF, and to refine the transformation parameters necessary to relate the national systems to ITRF. The densification may be carried out by individual countries by way of establishing GNSS networks through either continuous or semi continuous permanent GNSS stations.
- The third and equally important phase of the project will be to address the development of a more refined geoid model for Africa and the definition of a common vertical datum for the continent. The unification of national land levelling networks will follow from this. This phase of the project can run parallel to the two phases described above.

Countries will be expected to actively participate in the planning, management and execution of field campaigns, and in the processing, computation and interpretation of the observations in all phases of the project.. They will also be expected to maintain electrical and

communication facilities at the continuous permanent stations, and arrange for the delivery of requisite data sets to the data centres.

#### **4. ORGANISATION STRUCTURE**

The organization structure of AFREF is illustrated in Figure 2. The Steering Committee is nominated by United Nations Economic Commission of Africa, Committee on Development Information Science and Technology (CODIST). It is responsible for the continental coordination of the implementation of AFREF. It draws its membership from the United Nations, Regional Centres in surveys and mapping technologies, IAG and AFREF implementation regions as listed below;

- Regional Centre for Mapping of Resources for Development (RCMRD),
- African Organisation of Cartography and Remote Sensing (AOCRS),
- Regional Centre for Training in Aerospace Surveys (RECTAS),
- International Association of Geodesy(IAG) sub commission on reference frames and AFREF (SC 1.3d)
- Egypt, for NAFREF,
- Tanzania, for EAFREF
- Nigeria, for WAFREF
- Namibia, for SAFREF

The steering Committee liaises with international partners and a scientific advisory group and links them to the regional bodies and countries.

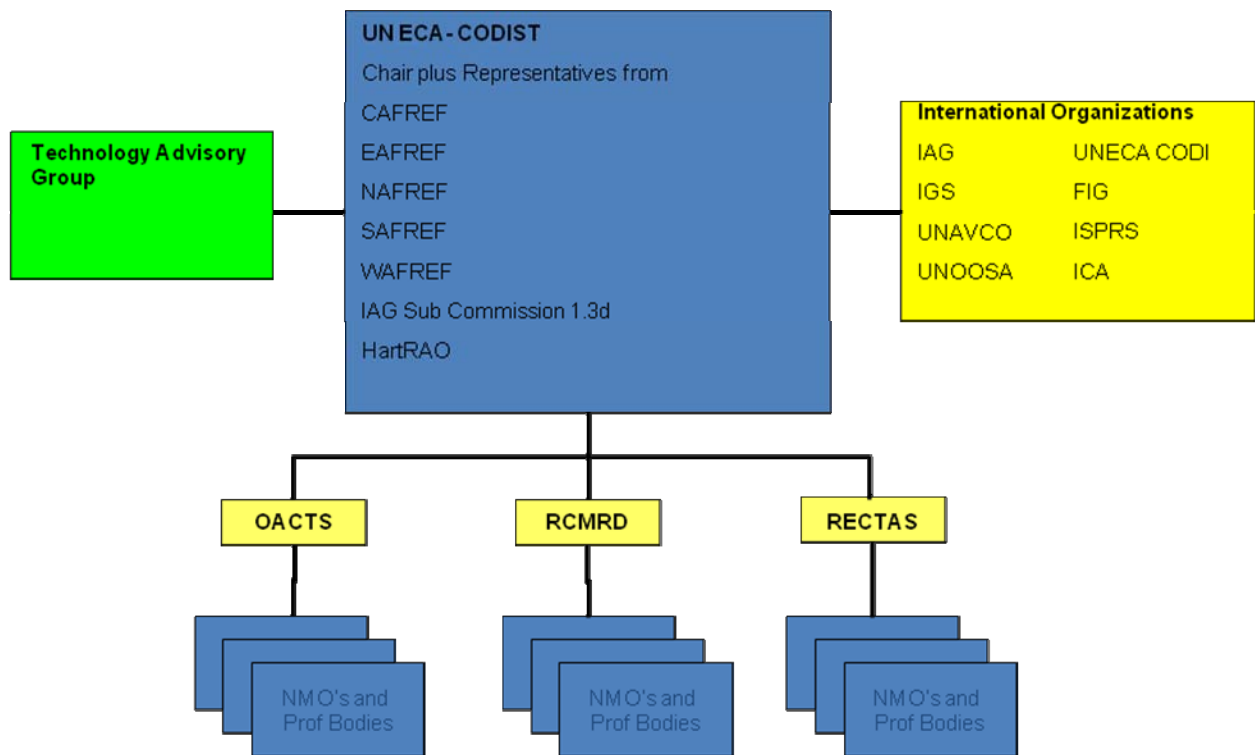


Figure 2. Organizational Structure

Regional bodies dealing with surveys and mapping disciplines including geo-information are expected to coordinate the implementation at regional level. Regional centres are expected to provide the linkages between the Steering Committee, regional working groups and National Surveys & Mapping Organization.

National Mapping Organizations (NMOs), whose responsibility amongst others is the establishment and maintenance of geodetic networks, are expected to lead and coordinate AFREF national implementation. NMOs should be supported by other GNSS stakeholders within the country. They are therefore expected to form working groups with participation from relevant public institutions and private sector including professional bodies such as surveyors, engineers and geophysicist. GNSS data users such as those in the transportation, aviation, construction, natural resources management and military should also be incorporated into the working groups.

National Mapping Organizations are members of UN ECA CODIST, Steering Committee, regional coordination working groups and finally national coordination and implementation working groups. The coordination bodies main function is to ensure commonality in funding and acquisition of hardware and software, implementation procedures, dissemination of data. The implementation is therefore national with regional and continental coordination.

## **5. REQUIRED RESOURCES**

Personnel and institutional resources are required at both national and regional levels. This requires persons well versed in the field of geodesy and particularly in establishing, manning, and processing of GNSS data and products. AFREF participants will be expected to use up-to-date positioning equipment, mainly GNSS of appropriate precision for the global network. These will include receivers and other ancillary components.

The permanent computing stations will need dedicated computers and storage peripherals to hold the data. Software packages and hardware are required for the processing of GNSS data. In the second phase of AFREF, software and expertise will be required for the re-computation and adjustment of national coordinate products to the new reference system for surveying, mapping and scientific communities.

Communications and network connectivity are essential components for the successful implementation of the reference network. AFREF being part of the global network, there will be constant need to upload and download data to and from designated data centres and IGS centres.

## **6. CURRENT STATUS**

### **Call for Participation**

The call invites organizations to participate by providing the resources to implement AFREF. The participation is open to a broad range of organizations such as National Mapping Organizations, Universities, research organizations, GNSS hardware and software vendors and donor community. UNECA was mandated to circulate the CFP to all prospective organizations identified by the Steering Committee. So far response was received from twenty eight organizations. Currently countries that have established at least one permanent reference station include Algeria, Benin, Egypt, Ivory Coast, Mozambique, Ghana, Kenya, Morocco, Niger, South Africa, Namibia, Zambia, Ivory Coast , Mozambique, Ethiopia, Tanzania, Malawi, Angola, Mauritius, Cameroon and Nigeria.

### **Workshops and Training**

The first technical workshop was held at the University of Cape Town, South Africa in July 2006. It drew participation from 30 African countries. World-renowned scientists on GNSS technologies attended and shared their knowledge and experiences. Participants discussed the modalities of the implementation of AFREF, such as setting up of tracking stations, data analysis centre and data holding centers.

Four AFREF and GNSS data processing training courses were held at Regional Centre for Mapping of Resources for Development (RCMRD), Kenya since 2006. The objective of the

courses were to equip geodesist with practical skills in the establishment and operation of Continuous Operating Reference Stations. Workshops were also held in Nigeria, Ghana, Ethiopia and Egypt, where many geodesist from African attended.

### **Installation guidelines for AFREF stations**

The AFREF scientific advisory group prepared a guideline document in January 2007. This document describes the necessary requirements and procedures that should be considered by participating organizations in order to qualify their stations to the part of the AFREF network. Accordingly to the volunteer nature of participation and the current phase of the AFREF project where the densification of the network is a major objective, the use of many strict rules is avoided. However, the AFREF stations must satisfy minimum standards in order to ensure the quality of the entire network.

### **AFREF website and Newsletter**

UNECA was requested to create a web site for AFREF. The website was created in May 2006 (<http://geoinfo.uneca.org/afref>). All papers and presentations relating to AFREF and the CFP are available on the site.

The idea to have a quarterly newsletter was conceived at the AFREF Steering Committee meeting held in July 2006 in Cape Town. The objective of the newsletter is to create a forum for discussions and exchange of information and experiences in the implementation of AFREF project. The first edition of the Newsletter came out in August 2006.

### **Data Holding Centres**

Some data from the established base stations is already being received by HartRAO data Centre in South Africa and the International GNSS Service (IGS). The AFREF Operational Data Centre (ODC) for the collection and dissemination of data from permanent GNSS stations in Africa went live at the beginning of June 2010. The Centre is operated by the South African National Geospatial Information Agency. GNSS data from all known stations that provide data on an open and free basis to users is collected and archived in the ODC. The ODC provides a one stop data base from which users can retrieve data. At present there are about 50 stations throughout Africa that contribute to the ODC. The address for the AFREF ODC is: [www.afrefdata.org](http://www.afrefdata.org). Data holding and analysis Centers are expected to be established by the end of 2011.

### **Data Processing Centre**

The AFREF programme has reached the stage where a selected set of data must be processed to provide a reference frame based on ITRF to which users can base all projects requiring a geospatial reference. National Mapping Organizations (NMOs) in Africa will be able to use the reference frame to realize national reference frames compatible with AFREF and,



therefore, ITRF. In addition, the reference frame must be monitored and updated to provide a dynamic reference frame and velocity vectors suitable for scientific applications.

In the next three months a call for participation for will be sought from all interested and capable organizations and institutions in the processing and analysis of GNSS data from the network of permanent GNSS base stations in Africa for the establishment of a uniform geodetic reference frame to be compatible with the ITRF. The areas of participation are :

- Processing and analysis of data from a network of permanent GNSS base stations together with the training and capacity building of geodesists and surveyors from African NMOs and Universities; and
- Development of continental and national reference frames based on data from the network of permanent GNSS base stations.

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## CONTACTS

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