The AFREF Project: Background, Rationale and Progress

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SUMMARY

A uniform co-ordinate reference system is fundamental to any project, application, service or product that requires some form of geo-referencing. Most countries in the world have established such reference systems that are used for national surveying, mapping, photogrammetry, remote sensing, Geographical Information Systems (GIS), development programs, and hazard mitigation (earthquake studies, fault motion, volcano monitoring, severe storms, etc). Many of these national co-ordinate systems are based on reference figures of the Earth which are somewhat outdated and, when based on a local origin or datum point, are restricted to a particular country, making cross-border or regional mapping, development, and planning projects very difficult indeed. In some instances, more than one datum has been used within a country. When using modern positioning technology such as GPS, technical understanding and careful mathematical manipulation is required to relate GPS derived co-ordinates to the national co-ordinate system upon which national surveying and mapping products and services are based. Many countries are therefore updating these national reference systems to be compatible with the global reference system and the GPS reference system in particular. On a continental scale, projects to unify the reference frames of the countries of Europe (EUREF), South America (SIRGAS) and North America have met with considerable success.

The African Reference Frame project, AFREF, has the primary objective of defining a continental reference system for Africa to be fully consistent and homogeneous with the global reference frame of the ITRF. This paper describes the background, rationale and progress made with AFREF since 2000.

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1. INTRODUCTION

In the context of global politics, the countries of Africa are considered to be developing countries. This has been clearly recognised by modern African leaders who, in October 2001, set up an initiative known as the New Partnership for Africa's Development (NEPAD) to pave the way for sustainable development on the continent. This sentiment has been set out in the introduction to NEPAD in which African leaders recognised "that they have a pressing duty to eradicate poverty and to place their countries, both individually and collectively, on a path of sustainable development, and, at the same time, to participate actively in the world economy and body politics." (NEPAD, 2001)

Many of the objectives and initiatives of NEPAD depend on the establishment and maintenance of sound regional or continental infrastructure of reliable geo-spatial information. It is essential, therefore, that the co-ordinate systems or foundation on which that information is based be both uniform and based on modern positioning technology throughout the region.

The Africa Reference Framework project (AFREF) is an African initiative with international support designed to unify the co-ordinate reference frames in Africa using Global Navigation Satellite Systems (GNSS) and, in particular, the Global Positioning System (GPS) as the primary positioning tool. The outcome of this project will be a uniform and consistent co-ordinate frame based on the International Terrestrial Reference System and Frame (ITRS and ITRF) covering Africa to be used as the fundamental reference frame for all regional and continental geo-spatial information and planning and development projects across a wide spectrum of disciplines. The AFREF project will, therefore, support the goals and initiatives of NEPAD.

2. RATIONALE AND BACKGROUND

One of the main long term objectives of the NEPAD is "to eradicate poverty in Africa and to place African countries, both individually and collectively, on a path of sustainable growth and development and thus halt the marginalisation of Africa in the globalisation process" (NEPAD, 2001). NEPAD was developed by African leaders and is based on national and regional priorities and development plans for the continent's renewal. A priority area of NEPAD is a focus "on the provision of essential regional public goods (such as transport, energy, water, ICT, disease eradication, environmental preservation, and provision of regional research capacity), as well as the promotion of intra-African trade and investments. The focus will be on rationalising the institutional framework for economic integration, by identifying common projects compatible with integrated country and regional development programmes, and on the harmonisation of economic and investment policies and practices." Any

meaningful regional development programmes will require maps and other geographic information products for effective planning and efficient implementation. As a result of the importance of geographic information, the science and technology platform of NEPAD includes an objective to "promote cross-border co-operation and connectivity" and an action to "establish regional co-operation on product standards development and dissemination, and on geographic information systems" (NEPAD, 2001)

The fundamental point of departure for any project, application, service or product which is reliant on some form of geo-referencing, must be a uniform and reliable co-ordinate reference system. Geographic information services and products provide the link between all activities and the places or locations where those activities take place. Most countries have developed co-ordinate reference frames based on an "off-the-shelf" reference frame which was most suitable for the particular country. Such reference frames were and, in most instances, are still being used for national surveying, mapping, remote sensing, Geographical Information Systems (GIS) and development programmes. Although these systems are in existence in many countries, the state of repair and extent of their applications varies considerably.

The importance of basing all geospatial information on a uniform co-ordinate reference frame has been recognized for many years. In 1905, Sir Sydney Burrard expressed, among other things, the following views on geodetic control (McCaw, 1929):

- geodetic control is of great practical use to prevent the accumlation of errors not only in the country itself but especially at the borders with neighbouring territories;
- geodetic control is of great benefit for the unification of disparate surveys within a country to base all surveys on one origin, to get rid of gaps and overlaps and to free the country from internal and external boundary disputes; and
- geodetic control reduces the cost of topographical, cadastral, engineering and mining surveys.

The above opinions as expressed over 100 years ago are not any different to those of today except that the current views consider entire continents. There are over 50 countries in Africa all of which are considered as developing nations and each with is own difficulties and challenges. Each of these countries has their own co-ordinate reference system and frame. Additionally, there are some countries that have more than one system each based on a different datum. Furthermore, a number of the former British colonies in Southern and East Africa adopted the Cape Datum co-ordinate system based on the Clarke 1880 spheroid but even these countries have different realizations of what, in name, is the same thing.

Although there remain a number of areas of conflict within Africa, there are also a number of regions where peace has been restored. With the restoration of peace has come the resurgence of development of these regions. The need to co-ordinate planning and development efforts within countries and across national borders in line with the ideals of NEPAD has become paramount and cannot be achieved successfully if the fundamental point of departure for these planning projects, i.e. the co-ordinate reference frame, is not uniform and of an appropriate modern standard (Windhoek Declaration, 2002).

The African Geodetic Reference Frame (AFREF) is conceived, therefore, as a unified geodetic reference frame for Africa. It will be the fundamental basis for the national three-dimensional reference networks fully consistent and homogeneous with the International Terrestrial Reference Frame (ITRF). When fully implemented, it will consist of a network of continuous, permanent GPS stations such that a user anywhere in Africa would have free access to the generated data and would be, at most, 1000km from such stations. Full implementation will include a unified vertical datum and support for efforts to establish a precise African geoid, in concert with the African Geoid project activities (Wonnacott, 2003).

Apart from being fundamental to all infrastructure, planning and development projects, AFREF and the network of permanent GPS base stations upon which it will be based, has vast potential for the promotion of geodesy and surveying, geo-information, earth and atmospheric science, disaster mitigation, the monitoring of crop and vegetation distribution and animal migration patterns. The implementation of AFREF and its applications will provide a major platform for the enhancement of skills and skills transfer in these sciences and further some of the objectives and actions of the NEPAD science and technology platform.

3. THE AFRICAN DOPPLER SURVEY

Prior to the introduction of GPS as an easily accessible positioning tool, the US Navy Navigation Satellite System, TRANSIT, was available to the geodetic and surveying community. The system was commonly known as the Doppler positioning system primarily because of the observing principal upon which it was based. In order to achieve the accuracies required for geodetic applications, it was essential that at least two receivers, preferably more, observed and recorded the Doppler shifted satellite transmitted signals simultaneously. The logistics of a survey extending over large areas with an inter-station spacing of 500 km or more to ensure that all stations recorded data simultaneously was not easy particularly with the added difficulty of poor telecommunications between stations.

In spite of these difficulties, however, a project was designed in the 1980's to unify the geodetic datums in Africa using Doppler as the primary observing tool. The project was known as the Africa Doppler Survey (ADOS). Doppler receivers were not, however, as readily available as GPS receivers are today and there were far fewer geodesists and surveyors experienced in the use of the equipment for geodetic applications than there today.

The main objectives of the ADOS project were (IAG, 1981):
- to provide zero-order control for future geodetic networks for mapping control;
- to provide control for datum unification and strengthening; and
- to provide an accurate geoid for Africa.

The project was planned and implemented by the IAG in conjunction with the African Association of Cartography (AAC), the United Nations Economic Commission for Africa (UNECA) and the Regional Centre for Mapping of Resources for Development (RCMRD). Field observations were carried out by African National Mapping Organisations (NMO's) and international geodetic organisations under bilateral agreements. Although nearly 300 zero

order points were established by the end of 1986, the goal to unify the geodetic datums in Africa was not met. The main reasons for this were:

- the logistics of carrying out the observations simultaneously proved exceptionally difficult indeed and limited the amount of suitable data;
- the rationale was not fully understood by participating countries resulting in a lack of motivation and enthusiasm for the project;
- the project was planned almost entirely by the IAG and the international community with little input from African countries;
- there were no set observing standards and procedures resulting in observations of unacceptable standard ; and
- the bilateral agreements between countries and sister organisations did not always materialize.

Although ADOS failed to meet its primary objectives, it did serve to provide a number of valuable lessons which will be carried forward into the AFREF project. Perhaps the most significant differences between the two projects has been the change in positioning technology notably the introduction of GPS, the concept of continuously operating GPS base stations, the establishment of the International GNSS Service (IGS) and its global network of GNSS (primarily GPS) base stations and the services and products derived from the IGS. It is now no longer essential that all roving receivers operate simultaneously since one is able to rely on the IGS global infrastructure of base stations. A set of standards and procedures has been introduced by the IGS for the establishment of permanent base stations. Apart from the technological changes, the fact that African countries are actively involved in the planning, managing and execution of AFREF will be a major positive feature and difference between this project and ADOS.

4. SIMILAR REGIONAL REFERENCE FRAME PROJECTS

Projects with similar goals and objectives have been undertaken elsewhere in the world. The European Reference Frame (EUREF) is perhaps the longest running and best established project of this nature to have been undertaken. EUREF was founded in 1987 as a Sub-Commission within the IAG and deals with the definition, realization and maintenance of the reference frame for Europe. It has matured to the stage where there are clearly defined sets of activities such as the establishment and maintenance of the European Terrestrial Reference System and European Vertical Reference System. These activities are based on a network of permanent GPS/GLONASS receivers (EUREF, 2005).

Similar projects have been established for South and Central America (SIRGAS), Asia-Pacific, North America and, although not entirely the same as others, Antarctica all of which are represented as Sub-Commissions of the IAG.

5. PROGRESS TO DATE

Since the Global Spatial Data Infrastructure meeting held in Cape Town in March 2000, where the need for a unified reference frame for Africa was first expressed, many meetings and workshops have been held to deal with AFREF either directly or indirectly. Currently, there are nearly 25 countries throughout Africa that have expressed interest in AFREF while the number of international organisations with interest in AFREF has also increased since the project was first proposed.

Perhaps the first meeting or workshop since the completion of ADOS dedicated to the unification of reference frames in Africa was held in Tunisia in May 2000. This workshop was attended by 6 North African countries and was largely of an exploratory nature to find ways and means of unifying datums in the region (Altamimi, 2004).

A similar, but unrelated meeting dedicated to AFREF, was held in Cape Town in March 2001 as part of the Conference of Southern African Surveyors (CONSAS). The purpose of this meeting was largely to try to gauge the level of interest in the project. Representatives attending the meeting were mainly from the National Mapping Organisations of Southern African countries as well as representatives from the IAG, IGS and EUREF. The consensus of opinion from attendees was that the project should go ahead and that the IAG should be the lead international organisation to give AFREF the necessary technical support. It was also recognised that AFREF must include both the horizontal and vertical components of a unified continental reference frame similar to EUREF. The logistics of undertaking a project involving more than 50 African countries was also recognised and for this reason AFREF has been organized on a regional basis. This concept has now become one of the fundamentals of the current organisational structure of AFREF.

The IAG was formally approached to support AFREF and to endorse the project at the European Geophysical Society (EGS) General Assembly in Nice in April 2001. At the EGS meeting in April the following year the wheels were set in motion within IAG to establish a formal structure within IAG itself to deal with AFREF. The North African component of AFREF, NAFREF, representing Algeria, Egypt, Libya, Morocco, Mauritania and Tunisia continued to meet. In October 2003 these countries signed a Protocol of Agreement with the IAG to work towards the attainment of a unified reference system for the region (Altamimi, 2004).

The US Government and the United Nations Office for Outer Space Affairs (UNOOSA) sponsored a regional workshop in Lusaka, Zambia in July 2002 on the “Use and Application of Global Navigation Satellite Systems (GNSS)”. The workshop was the fourth in a series The first three of which had been held in South America, Eastern Europe, South East Asia. The Lusaka workshop was the fourth in the series and included the African and Middle Eastern regions. An important aspect of the workshop was that there was a good representation of countries from all regions in Africa. One of the major recommendations on Surveying, Mapping and Earth Science emanating from the UNOOSA report (UNOOSA, 2003) on the four workshops was to:

"Establish a continental reference for Africa, or African Reference Frame (AFREF), consistent with the International Terrestrial Reference Frame (ITRF)".

6. THE WINDHOEK DECLARATION

The next important milestone was a workshop held in Windhoek, Namibia in December 2002 prior to the Regional Centre for Mapping of Resources for Development (RCMRD) technical meetings. The important feature of the workshop was the preparation of the "Windhoek Declaration" in which the 8 Southern and East African countries represented at the meeting including the RCMRD, committed themselves to support AFREF and its objectives and principles. The declaration was accepted by the United Nations Committee for Development Information (CODI) and formed the basis upon which CODI - Geographical Information (CODI-GEO) established an AFREF working group in August 2004.

In broad terms the "Windhoek Declaration of an African Geodetic Reference Frame (AFREF)" was a commitment made by the 8 East and Southern African countries to:

- support the AFREF project;
- publicize and promote the project within their respective Governments and appropriate international organizations

and that;

- the UN Economic Commission for Africa (UNECA) should accept the principles and concepts of AFREF and that these be accepted by the UNECA Committee on development Information (UN CODI) for implementation;
- the UN Office for Outer Space Affairs (UNOOSA) be requested to support the project; and
- the IAG and its service organization, the IGS, be requested to continue to support the project and assist with its implementation.

On consideration of the above, most of these principles have or are in the process of being met. The "Windhoek Declaration" was accepted as a formal document by the UN CODI in May 2003 and AFREF became a formal project within the CODI-Geographical Information (CODI-GEO) sub-committee. One of the driving principles upon which AFREF has been established is that the project must be designed, managed and executed from within Africa with technical assistance and expertise being provided by the international geodetic community. In addition to this, the concept of continental coordination with regional and national implementation has been paramount. The structure of the CODI-GEO Working Group on AFREF was accepted at a workshop hosted by the African Association of Remote Sensing of the Environment (AARSE) in Nairobi in October 2004 and further refined at meetings held during the FIG Working Week in Cairo in April 2005.

The structure shown in Figure 2 reflects the broad concept of AFREF that:

- it is to be designed, managed and executed from within Africa;
- it is to be organized on a regional basis;
- it is to be executed at the national level; and

- technical expertise and support will come from the international geodetic community as well as scientists and technologists from African countries. The role of technologists in the Science and Technology Group will be largely to advise the project on matters such as the strategy from a scientific view point and telecommunication and power supply aspects unique to Africa.

The importance of the regional centres cannot be underplayed as, collectively, they already represent a reasonably high percentage of African countries. They have an important role to play in the "regional" aspect of AFREF and are better equipped to communicate and liaise with their member countries. Starting from the North, l'Organisation Africaine de Cartographie et de Teledetection (OACT) represents largely the Arab speaking countries of that region, while in West Africa, the Regional Centre for Training in Aerospace Surveys (RECTAS) represents both French and English speaking West African countries. The Regional Centre for Mapping of Resources for Development (RCMRD) represents a reasonably large number of East and Southern African countries.

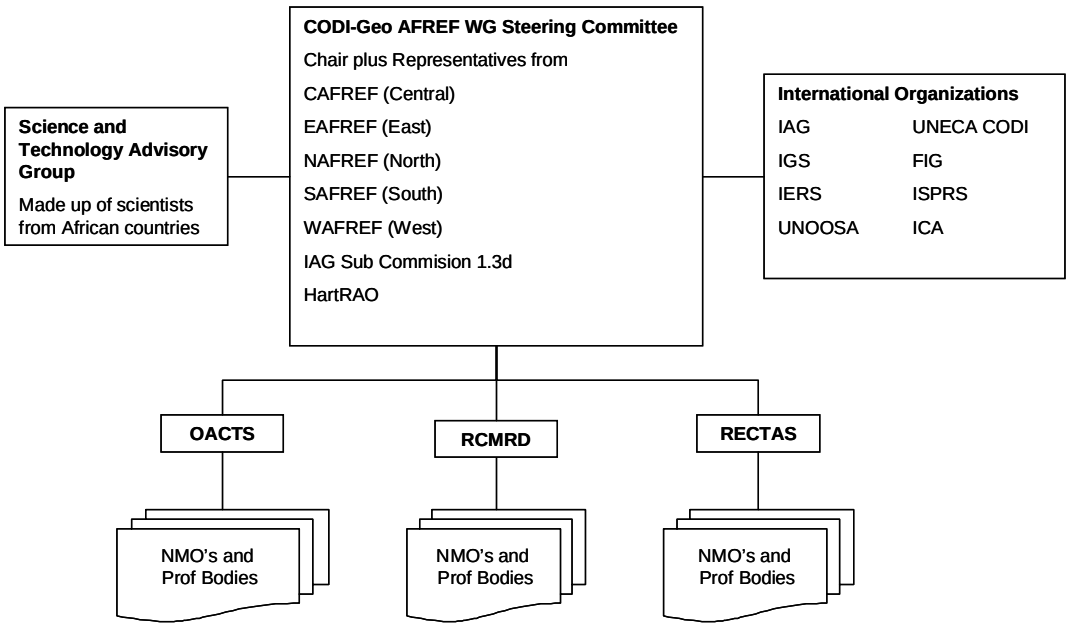

Figure 1: Organizational structure of CODI-GEO Working Group on AFREF.

Perhaps the most important role players in the project are the National Mapping Organisations. The NMO's are going to be responsible for the implementation of all phases of the project from the installation and operation of GPS base stations right through to the final conversion to ITRF of the National reference frames for which they are responsible. Even once the conversion is complete, historical data based on previous systems will also have to be converted where necessary. This is particularly the case of cadastral records for taxation purposes and to ensure the continuity of security of title.

The Hartebeesthoek Radio Astronomy Observatory (HartRAO) in South Africa also has an important role to play in AFREF. It is the only facility in Africa that is a regional data centre for the IGS and it is therefore natural that all data generated by the permanent GPS base stations should be archived at HartRAO. This, however, does not exclude the regional centres from archiving data from their respective regions. HartRAO is also important in that it is one of very few facilities globally where VLBI, SLR, GPS, DORIS and GLONASS are all co-located at the same site.

7. AIMS AND OBJECTIVES OF AFREF

In July 2002, an application for financial assistance for AFREF was submitted on behalf of the IUGG/IAG and other organisations to the International Council for Science (ICSU). The application was unfortunately not successful but in preparing the application some focus was placed on formulating the objectives of AFREF which, since then, have become the cornerstone of the project. These objectives are to (Neilan & Wonnacott, 2002):

- define the continental reference system of Africa. Establish and maintain a unified geodetic reference network as the fundamental basis for the national 3-d reference networks fully consistent and homogeneous with the global reference frame of the ITRF;
- realize a unified vertical datum and support efforts to establish a precise African geoid, in concert with the African Geoid project activities;
- establish continuous, permanent GPS stations such that each nation or each user has free access to the generated data, and is at most 1000km from, such stations;
- provide a sustainable development environment for technology transfer, so that these activities will enhance the national networks and numerous related applications with readily available technology;
- understand the necessary geodetic requirements of participating national and international agencies; and
- assist in establishing in-country expertise for implementation, operations, processing and analyses of modern geodetic techniques, primarily GPS.

One of the major objectives of the AFREF project is the transfer of skills and the enhancement of in-country expertise in the operation and application of GPS observations for geodetic purposes. This is vitally important if African countries and their NMOs are to be major role players in the conversion or transformation of current national geodetic reference frames to an ITRF base frame. To this end, a technical workshop is planned to take place in Cape Town early in 2006 to which representatives from the NMOs will be invited to attend. Specialists in topics such as the IERS and ITRF, the establishment and operation of continuous GPS base stations etc will be invited to conduct lectures in their fields of speciality.

8. PRESENT SITUATION

From an organizational point of view, a working group has been established by CODI-GEO to manage AFREF which enjoys the support of numerous international organizations that are capable of giving the project technical support. Apart from technical support, these organizations, which include the IAG, IGS, IERS, UNOOSA, UNECA CODI, FIG, ICA and ISPRS among others, are able to leverage financial assistance from donor organisations, countries and equipment manufacturers. To strengthen this support, the IAG has established Sub-Commission 1.3d Africa within its Commission 1 Reference Frames. In addition to the establishment of this Sub-Commission, the IGS, a service organization of the IAG has come out very strongly in support of AFREF.

From an infrastructure point of view, there are already at least 15 IGS stations in Africa equipped with GPS receivers. The quality and regularity of data reception from these stations varies considerably and although it would appear that a station exists at a certain location, a continuous flow of data may be somewhat intermittent or even have ceased altogether. There are also a number of continuously operating base stations which have been installed according to IGS standards but have not been registered as such. This is the case within South Africa where a network of 38 stations is currently in operation. There may be other similar cases such as continuous base stations at major airports or scientific institutions and which may be suitable IGS stations provided some antenna and receiver upgrades are undertaken. Figure 3 shows the distribution of IGS registered space observing techniques in Africa.

There are many contractors and developers working in Africa who require geospatial information and maps as part of their contracts. The mapping and geospatial information that is available from the NMOs is normally based on the National co-ordinate systems currently in use in the particular country. These are based on old reference frames and are generally not compatible with modern positioning technology and the GPS reference frame, WGS84. The result is that, although contractors use GPS as the fundamental positioning tool, a multitude of loosely related local co-ordinate systems are being established.

Figure 2: Distribution of GPS, GLONASS, SLR, VLBI and DORIS observing systems in Africa. (http://cddis.gsfc.nasa.gov/doc/africamap.gif viewed 15 January 2005)

9. THE WAY FORWARD

With organisational structures in place to deal with AFREF and a wide range of international organisations having committed themselves to giving the project their support, the time is fast approaching to commence with the establishment of a continental wide network of permanent GPS base stations. Clearly, funding for the purchase of receivers and ancillary equipment is necessary and perhaps the next phase will be to secure sufficient funding to install an initial network of about 25 base stations throughout Africa. Besides the cost of equipment and installation, ongoing funding will be required for telecommunication and maintenance of the network to ensure a continuous flow of data and to maintain the network. Experience has shown that although such networks are called “continuous”, this is very rarely the case because of various equipment, power and telecommunication failures which all require some form of maintenance funding. It has been estimated that the cost of equipment for 25 stations will be approximately $US1.1 million. In addition, telecommunication and maintenance costs

for these stations will be approximately $US50000 per annum to ensure the sustainabilty of the project.

The selection of suitable sites for base stations is going to be dictated by a number of factors:
- the availability of reliable telecommunications is perhaps the most crucial aspect of this phase of the project which could cause the project to fail if this is not dealt with very carefully. It has been said that the operation of networks of permanent GPS base stations is more of a telecommunication exercise than a GPS problem;
- a suitable and reliable power source must be available and could include making use of solar panels if necessary;
- naturally, with all this equipment installed on site, the security and safety of the site is important; and
- the stability of the antenna monument foundation and clear sky view are critical success factors from a geodetic point of view.

Site selection is going to be a task that will rely heavily on the local knowledge of the NMO's and here major airports, Government and University buildings or surrounds could be considered for the construction of antenna sites.

The installation and operation of a network of permanent base stations is the first phase of the AFREF project. The whole purpose of the project is to convert the current national reference frames to internationally accepted reference frame such as the ITRF2000 to be able to unify the frames throughout Africa. This will entail a great deal of work, effort and commitment by African NMO's to survey, process and carry out the computations using the permanent base stations as a fundamental reference frame. The conversion of all mapping and other geospatial information will follow and will probably take even longer than the conversion to an ITRS/ ITRF based co-ordinate system.

An aspect of this project that is prone to be forgotten is the computation of a reliable geoid for Africa and the unification of the vertical reference frames. The IAG Africa Geoid project is being organised under the auspices of IAG Commission 2 Gravity Field and has been established by IAG Commission 2 (IAG, 2003) to:

- "determine the most complete and accurate geoid model for Africa that can be obtained from the available data; and
- foster co-operation between African geodesists and to provide high-level training in geoid computation to African geodesists."

Although the Africa Geoid project falls under a different IAG commission, the two projects are, nevertheless, complementary.

A drive to encourage countries and organisations to participate in the project has been intiated by the AFREF Steering Committe by publishing a "Call for Participation in the Unification of African Reference Frames" in which project participants and potential particpants are requested to submit a letter of intent to formally commit to the project. Participating

organisations would be National Mapping Organisations, academic and scientific institutions, manufacturers and vendors of GNSS and related ancillary equipment and so on (IGS (2005), UNECA (2005)).

One of the stated objectives of the project is the transfer of skills and capacity building of geodesists and surveyors in Africa. To this end, a four day technical workshop is to be held in Cape Town in July 2006 and will cover topics such as co-ordinate reference systems and frames, general GNSS technology and, in particular, permanent GNSS stations and data processing and analysis.

10. CONCLUSION

The goals and objectives of AFREF will support and satisfy many of the objectives of NEPAD. An organisational structure is in place that reflects the fundamental principle that the project be planned, managed and executed by Africans with technical assistance and support from the international geodetic community. The time is ripe, therefore, to commence with the first phase of the project notably the installation of a network permanent GNSS stations. The project must not be considered as a short term one but will take a number of years to complete which will require the long-term commitment of National Mapping Organisations. As stated in the Windhoek Declaration, the attainment of a unified three dimensional geodetic reference frame for Africa is not the only major objective of the project. The transfer of the skills to Africa necessary to undertake a project of this nature and to create a large pool of geodesists, surveyors, IT specialists and related skills is of paramount importance for the success of AFREF and for future similar continental, regional, national or local projects.

REFERENCES

Altamimi, Z (2004): "Status of AFREF Project." Proceedings of International GPS Service 10th Anniversary Symposium, Bern, Switzerland, March 1-5 2004.

EUREF (2005): http://www.euref-iag.net viewed February 2006.

IAG (1981): "Proposal for African Doppler Survey: ADOS." Prepared for the ADOS Planning Sessions during the 2nd Symposium on Geodesy in Africa, Nairobi, Kenya, November 8-14, 1981.

IAG (2003): http://www.ceegs.ohio-state.edu/iag-commission2/cp2.3.htm viewed February 2006.

IGS (2005): "AFREF Call for Participation." http://igscb.jpl.nasa.gov/ viewed February 2006.

McCaw, GT (1929): "The African Arc of Meridian." Paper presented at Meeting of British Association for Advancement of Science, August 1929, South Afriacn Survey Journal, Vol IV, July 1931-March 1936.

NEPAD (2001): http://www.nepad.org/ viewed February 2006.

Neilan, R, & Wonnacott, R (2002): "Establishing A Continental Reference System in Africa: AFREF" Proposal to International Council for Science on behalf of International Union of Geodesy and Geophysics/International Association of Geodesy, International GPS Service/International Earth Rotation Service and International Society of Photogrammetry and Remote Sensing.

UNECA (2005) ”Call for Participation in the Unification of African Reference Frames.” http://geoinfo.uneca.org/afref/AFREF_CFP.pdf viewed February 2006.
Wonnacott, R (2003): “A Continental Reference Frame for Africa: AFREF: Southern and East African Components (SAFREF and EAFREF)” Report to the International Association of Geodesy for the period 1999 – 2003.
Wonnacott, R (2005): ”AFREF: Background and Progress towards a Unified Reference System for Africa” Proceedings of International Federarion of Surveyors (FIG) Working Week, Cairo, Egypt, 16 – 21 April 2005.

BIOGRAPHICAL NOTES

Richard Wonnacott completed a BSc Survey degree in 1974 and an MSc (Eng) in 2005 at the University of Cape Town (UCT), South Africa. He registered as a professional land surveyor in South Africa in 1976. He has been employed by the Chief Directorate: Surveys and Mapping (CDSM) since 1976. He initiated and is currently project manager for the South African network of permanent GPS base stations. He has presented papers at numerous national and international conferences and was the South African National correspondent and representative to IAG from 1993 to 2004. He is currently the Chairman of IAG Sub-Commission 1.3d Africa and is a member of the CODI-GEO Steering committee on AFREF. He also an Associate Member of the IGS.

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