THE IMPLEMENTATION OF THE GLOBAL NAVIGATION SATELLITE SYSTEM (GNSS) IN NIGERIA: The Challenges.

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Abstract

The Global Navigation Satellite Systems (GNSS) is extremely valuable tool across a broad range of applications, creating opportunities for regional and international technological advances in the areas of positioning and location-based services, surveying and mapping, disaster management, air, land and sea navigation, food security and emergency response. GNSS technology provides opportunity for developing countries to take advantage of applications that improves the quality of life, social and economic progress and support priorities for sustainable development. Whereas the developed countries has fully recognized and taken advantage of this technology, the developing countries like Nigeria is woefully underutilizing it to the detriment of her economic and social development. Despite the launch of a communication satellite (NigComSat-1) by the Nigerian government carrying two L-band payload for GNSS augmentation purposes, there is no good government policies towards the establishment of GNSS technology, human resource development, public and private sensitization and participation for the effective utilization of GNSS technology. This paper highlights some of the challenges facing Nigeria towards the realization of GNSS technology and proposes a framework for the implementation of GNSS in Nigeria.

Key words: AFREF, GNSS infrastructure, Institutional framework, NigComSat-1, Nigerian geodetic reference system

1.0 Introduction

The GNSS technology has gained a worldwide acceptability over the last decade with promising accessibility, precision, economical as well as sustainability. However, the developing countries have been underutilizing GNSS not only because of the perceived high cost and complexity of the GNSS equipment and its infrastructure, but also sceptical about the accuracies of their output. This perception continues to widen the gab between the developed and the developing countries thereby delaying the implementation of GNSS and the benefits the developing countries could derived from such a system. In order to help the developing countries take advantage of GNSS to improve the quality of life, benefit social and economic progress, support priorities for sustainable development (Ashkenazi, 2005); the United Nations Office for the Outer Space Affairs have been in the forefront of putting in place series of workshops and seminars within the framework of the United Nations Programme on Space Application with emphasis on capacity building in the use of GNSS in various applications.

In December 2003, the Federal Government of Nigeria announced its intention to develop its own satellite L-band navigation payload for Satellite Based Augmentation System (SBAS), on the proposed Nigeria Communication Satellite, $450 million to cover the African Continent (Rufai, 2003). The initiative came as result of increased awareness on GNSS from regional workshops. The intention is to provide seamless navigation services over Africa. Furthermore, Nigeria has declared her openness and willingness for strategic partnerships with system providers (particularly the Galileo and GPS). In April 2005, it was announced that China has been awarded a contract to develop and launch a dedicated communication satellite for Nigeria in 2007. The contractor is understood to be the China Aerospace Science and Technology Corporation and the Chinese Academy of Space Technology (CAST).

The Nigerian Communication Satellite (NigComSat-1) was finally launched in March 2007. The NigComSat-1 carries two L-band payload for GNSS augmentation purposes. However, the realization of the application areas, couple with the lack of ground infrastructure and institutional framework poses danger to the sustainability of the system and GNSS implementation at large.

2.0 GNSS Components

The Global Navigation Satellite System (GNSS) is a space-based radio positioning system that includes one or more satellite constellations, augmented as necessary to support the intended operation, and that provides 24-hour three-dimensional position, velocity and time information to suitably equipped users anywhere on, or near the surface of the earth.

GNSS is a generic term covering a number of existing and planned constellations of satellites together with supporting infrastructure systems, used for determining positions across the globe. They are coordinated with data communications methods such as radio or the Internet, playing key role in the operation of powerful, integrated information management and control systems with a diverse range of applications affecting many parts of the national and regional economies. The core elements of GNSS include: the Global Positioning System (GPS), the Global Orbiting Navigation Satellite System (GLONASS), and the planned Galileo system.

Fig. 1. GNSS Satellites Nominal Constellation

Countries can be categorized into three groups in terms of the utilization of the GNSS technology. Those countries that own the satellite vehicles that generate the signal in space which includes the United States of America (USA) owners of the GPS, Russia, owners of the GLONASS and the European Union, owners of the yet to be launched Galileo (currently at testing mode). The second group are those countries that have developed augmentation systems that improve the signals from the navigation satellites. Such improvements include; the provision of wide-area correction models for the satellite orbits, clocks and ionosphere, provision of integrity messages on satellite health and performance status, provision of additional ranging signals, enabling additional observations to be made. The second group include India, owners of GANGAN; Japan, owners of MSAS; Australia, owners of GRAS; USA owners of WASS, and EGNOS for

Europe. The third group includes countries that are yet to develop neither satellite vehicle nor augmentation system but however, might have the capability of having their own satellite developed and launched by other country. Such countries are characterized by lack of the needed GNSS infrastructure, expertise, and motivation to adopt the technology as expected. It is in this category that Nigeria belongs.

3.0 Required GNSS Infrastructure

3.1 National Datum

Geocentric Reference System is a geodetic system for the determination of geometric position. The realization of the World Geodetic System (WGS) with its origin in the centre of mass of the earth has brought about having a reference system with global and regional applications. The current WGS84 was realized with the coordinates of a catalogue of over 1,500 world-wide geodetic stations (Rizos, 1999). The system has its Z-axis along the assumed rotation of the earth, X-axis along the prime meridian and the Y-axis forming a right-hand cartesian coordinate system in used globally for positioning and navigation.

The linking of WGS84 to the national datum is an essential requirement for the establishment of GNSS in any country. This required the use of acceptable national transformation parameters, to convert the GNSS data onto the national coordinate system and vice versa. These parameters will then be used as a standard for all GNSS activities.

3.2 Augmentation System

Nigeria and Africa in general by the virtue of its geographical location, stands to benefit in a no small measure if Range and Integrity Monitoring Stations (RIMS) of the EGNOS and WASS augmentation systems are installed. This will provide the accuracy, integrity, reliability and continuity of the GNSS signals and thereby ensuring the safety of life and promoting the potential application of the system. Figures 2a and 2b show the foot print of the EGNOS and WASS over the African region.

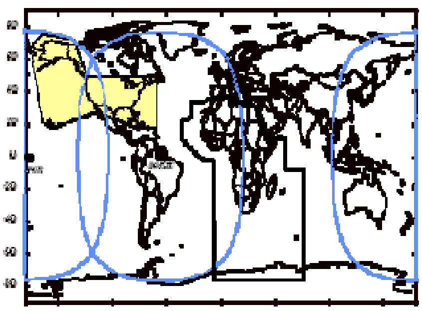

Fig. 2a. Foot print of WASS

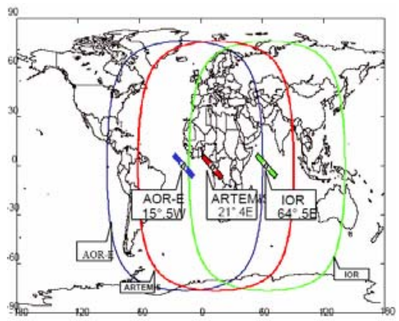

Fig. 2b. Foot print of EGNOS

Nigeria has coverage of the two augmentation systems, particularly, triple coverage of the EGNOS geostationary satellites, IMMARSAT-II AOR-E, ESA's ARTEMIS and IMARSAT III. As one of the third group earlier mentioned, the Nigerian Communication Satellite (NigComSat-1) was launched in March 2007. It is designed to meet the telecommunication, broadcasting and broadband need. In addition, is carries the two L-band payload said to be for GNSS augmentation purposes. It has a strong foot print covering the Economic Community of West African States (ECOWAS), having the potential of exploiting the virgin market in the sub-Saharan Africa and hence providing augmentations for GNSS services (Borrifice, 2006).

3.3 Continuously Operating Reference Station (CORS)

Over the last decade, several Continuous Operating Reference Stations (CORS) have been deployed by various nations to support very high accuracy geodetic applications (Rizos, et al 2003). CORS are important enhancement to a range of GNSS activities such as surveying, mapping and navigation. They improve the efficiency and accuracy of the activities they support. A CORS is made up of GPS receivers, antenna, computers, and power supply and communication protocol to the outside world through broadcasting of corrections to users. The roving receiver applies the differential corrections in real-time or in post-processed mode.

3.4 Digital Maps

The development and use of digital maps has been on the increase over the last 10 years. They are incredible dense carriers of spatial information either as standalone or as additions to text. Maps provide safety relevant information as a tool and also a by-product of GNSS. They are interface with other platforms to provide location and other value added services.

3.5 Communication

Communication is a vital organ in the drive to ensure the sustainability of the GNSS technology. With the rapid advances in wide accessibility of internet technology without data transmission range limitation, internet-based GNSS are very much efficient and could serve as an alternative to radio-based system. GNSS also makes use of wireless broadcasting e.g. GSM to link roving receiver with the base station.

4.0 GNSS Challenges in Nigeria

The successful introduction of GNSS depends on the definition and implementation of an institutional mechanism that guides a well-planned transition into the world of satellite navigation (Henaku, 1999). Considering the abundant human and natural resources in Nigeria, the need to taking full advantage of the GNSS technology can not be over emphasized. This can be realised if all professionals in GNSS and related fields come together to analyze the strengths, weaknesses, opportunities and threats of the GNSS technology in the context of the Nigerian environment; and work out a National GNSS Master Plan (NGMP). In order to achieve this, the following challenges must be considered.

4.1 The Nigerian Geodetic Reference System

The observation of the Nigerian geodetic reference system was carried out between the late 1940's and early 1960's (Arinola, 2006). The reference ellipsoid is the Clarke 1880 with the centre and origin not in coincidence with the Earth's centre of mass. Rather, the origin is one of the stations located roughly at the centre of the associated triangulation network (Onyeka, 2006). The geodetic reference system is based on Minna Datum which is a local datum with origin of the coordinate adopted. Figure 3 shows the Nigerian geodetic triangulation network. The controls were established using the traditional survey methods.

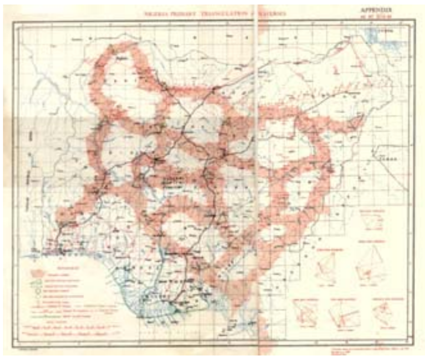

Fig. 3. The Nigerian Primary Triangulation Network

The Minna datum used in the production of the Nigerian primary triangulation network has a number of inherent deficiencies resulting to serious distortion in the network. Some of these problems include (Uzodinma, 2005):

i. In-accuracy of the scale factor by compression of the Clarke 1880 ellipsoid, thereby causing defect in distances measured.

ii. The origin of the Nigerian network is poorly defined

iii. There is absence of geoidal height model

iv. Difficulties in the determination of the transformation parameters. Nigeria is yet to come out with workable transformation parameters for the whole country, hence the local reference system cannot be transformed to WGS84, given the defects and deficiencies earlier mentioned.

4.2 National Geospatial Data Infrastructure.

The status of spatial data infrastructure in Nigeria is rather poor. National Geospatial Data Infrastructure (NGDI) provides a base or structure of practices and relationship among data providers and users that facilitate data sharing and usage (Nwilo and Osanwuta, 2006). The implementation of GNSS requires the establishment of a National Spatial Data Infrastructure. However, this can not be achieved without a well defined and distributed homogenous control network, a good geodetic reference datum, and well developed geoid. This all depend heavily on related activities such as survey coordinates, waterways, road, railway networks, electricity supply communication and other specialized human activities.

The Federal Survey Department charged with the responsibility of all geodetic activities has not covered the region with primary controls. Most of the geodetic controls are through the traditional survey methods and in analogue format. The implementation of the satellite techniques is still far from being realized.

4.3 Funding

Once the use of a space technology and application has been integrated into the broader context national and regional development priorities, funding need to be secured. The availability of funds will enhance the expansion of infrastructure and its sustainability through maintenance interventions (UN, 2002). There are various sources and mechanisms for funding GNSS. This could be from government or private donor. There is therefore the need to understand the mandates of such funding institution and the specific criteria established for specific funding programmes. The National Space and Research and Development Agency (NASRDA) should be the vanguard in this regard.

4.4 Other aspects of challenges and remedying:

i. Capacity building especially in human resources

ii. Education and sensitization of the public especially the policy makers. This should be in the form of seminars, workshops and symposium targeting decision makers and potential users of GNSS as well.

iii. Formation of GNSS group of experts at the national level proving expertise and advice and involve in various stages of implementation.

iv. Establishing marketing strategies of exploring areas of economic benefit and how it could be sustained.

v. Developing a system that will be demand driven and incorporating other technologies such as remote sensing, map matching etc.

vi. Involve in collaborative efforts with other international organs and countries. Similarly, involve in an extensive collaboration with institutions of higher learning in support of the needed human resources.

5.0 The AFREF Project

At present, the African countries traditionally maintained their own geodetic reference systems. This has resulted to maps in neighbouring countries not edge-matching properly at the borders, thereby resulting to lots of border conflicts and loss of lives. The concept of a unified geodetic datum for Africa has been on the drawing board for the past one and half decades. The African Reference Frame (AFREF) is conceived as a unified geodetic reference for Africa to be the fundamental basis for the national and regional 3D reference networks (Farah et al, 2006). Efforts are going on with series of seminars and workshops sensitizing the stakeholders on the urgent need of implementing the long awaited unification. When fully implemented, it will consist of a network of permanent GNSS stations, continuous or otherwise such that, a user any where in Africa would have free access to GNSS data and products. The realization of AFREF has vast potentials for geodesy, mapping, surveying, geo-information, natural hazards mitigation etc. its implementation will provide a major springboard for the transfer and enhancement of shill and knowledge in GNSS. Nigeria is involved in this campaign.

6.0 Establishment of Institutional Framework

For a successful implementation of the Global Navigation Satellite System (GNSS), there is a need to for a national policy that will provide the necessary guidelines, identify the various stakeholders for various aspects of the GNSS implementation. The framework should include a collaborative mode among the providers, providing favourable and flexible mechanisms where there will be a shared interest in the use of the GNSS irrespective of the region in which they operate.

The institutional models for the provision of GNSS include:

i. Coordination among GNSS System/Signal provider

System providers should work towards a reduction in the complexity and cost of user equipment by pursuing greater compatibility and interoperability with other augmentation systems such as WAAS and EGNOS, which include signal structure and the geodetic reference standards. There should be continuity and integrity of services, as such the need for cooperation with the administrators for which the services are offered. This will guide against interference with the infrastructure put in place. Similarly continuity in the reception of the GNSS signal is a matter of priority, there should be a protection of the radio spectrum allocated from interference both at domestic and international. [Sullivan et al, 2001]

ii. Information dissemination

The link between the system provider, service providers, users and equipment manufacturers should be ensured. Such a link should involve the provision of information on the GNSS system status at any time. This may include satellite health, outages etc. This information is necessary, as they will have direct impact on the type of service available for any particular GNSS application. The provision of timely warning is a crucial issue that can not be compromised, it is therefore important to note that, the dependency of user on GNSS is greater compare to other services such as telecommunications, utilities, electrical etc.

iii. Feedback from Users

There is need for feedback from the end-users of the GNSS. This will enable the system providers and service providers to meet up with the demand of the users and ensuring efficiency of the system.

Fig. 4. show a proposed GNSS national framework. The national framework is a prerequisite for many multi-disciplinary applications. Besides the establishment of a national geodetic reference system and the development of a nation geoid, a key outcome of the GNSS implementation will be the conversion of all national surveying and mapping products to the same common reference system. This shall be possible through the determination of the transformation parameters from local system to WGS84. A practical outcome of this will be the ease with which cross-border and regional geo-referenced projects can be carried out.

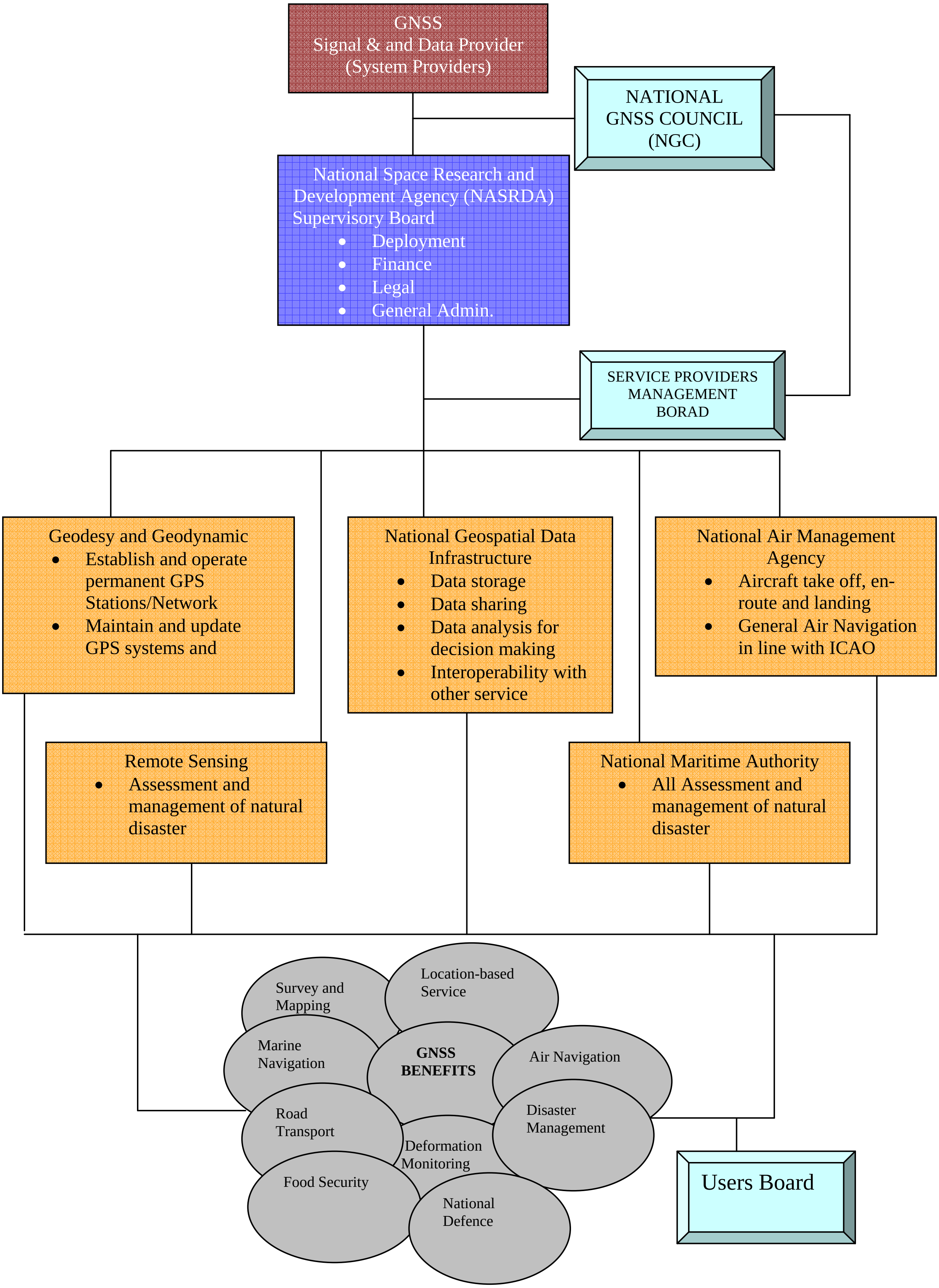

Fig. 4. Proposed GNSS National Framework

7.0 Economic and Social Benefits to Nigeria

The Government is to work cooperatively with the private sector to maximise the economy, social and environmental benefits of an integrated institutional, technical, educational and legislative GNSS-related infrastructure. This infrastructure will enhance public safety; facilitate the development and use of present and future applications of GNSS; facilitate the use of GNSS services across multiple modes and applications and its integration with other technologies; accommodate present and future demand for GNSS-related functionality; be domestically and globally interoperable; contribute to environmentally sustainable outcomes; and be compatible with national security requirements. The strategic principles on which to work towards include: national coverage, Safety, Efficiency, economic and social benefits and Industry development (Rizos, 2003)

The Nigerian community should be ready to play an active role in satellite navigation and position services by participating in the implementation of a global system that answers the need of all civil users. The reason is that, the potential market of the navigation is enormous. The Nigerian aviation industry appears to be in the forefront in generating most of the interest in satellite navigation followed by survey and mapping. Other sectors include, road transport, telecommunication, security, emergency, traffic management and agriculture, and will account for most of the revenue in the short to medium term. GNSS will in turn reduce waiting times, fuel savings, better environmental protection and reduction in the number of accidents.

8.0 Conclusions

The immediate and exponential benefits that will be offered by GNSS will result in a safer and more efficient infrastructure, which can positively influence trade potential and economic viability of Nigeria. GNSS can truly serve as a catalyst for trade and economic growth of the country for taking advantage of it. Clear government policy, with a national multimodal approach to GNSS related issues, will benefit service providers (both public and private sector), service users and the Nigerian population.

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