# The Applications of Sacredion Online GNSS Positioning Service (SOGPOS) for Real-Time Kinematic GNSS Correction in Asset Mapping Management (12563)

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***Keywords:*** GNSS-CORS, SOGPOS, Satellite-Positioning, Users' Access, Correction-Service

## SUMMARY

In this paper, the Sacredion Online GNSS Positioning Service (SOGPOS), a network of ten (10) Continuously Operating Reference Stations (CORS) is explored. SOGPOS infrastructure includes a network of CORS, communication channels, data processing, distribution system, user management, maintenance, and coordinate system in International Terrestrial Reference Frame (ITRF) 2014. The paper discusses the importance of establishing a reliable and accurate GNSS infrastructure to provide positioning data to users in various sectors, such as transportation, agriculture, construction, and surveying. The SOGPOS system is a cloud-based GNSS positioning service that provides static GNSS data and real-time high-precision positioning correction to users in Nigeria. The SOGPOS CORS network was established in collaboration with the Nigerian Institution of Surveyors at various state branches. The paper highlights the SOGPOS user management features, GNSS Services availability, and reliability of the positioning data. Finally, the paper concludes by discussing the potential of a GNSS infrastructure such as SOGPOS in advancing various sectors and improving the accuracy and reliability of positioning data in city development, mining, and exploration, deformation monitoring in buildings, natural disaster monitoring, and weather forecasting, for the purpose of ensuring the sustainability of natural and manmade assets in line with the United Nations Sustainable Development Goals (SDGs).

# The Applications of Sacredion Online GNSS Positioning Service (SOGPOS) for Real-Time Kinematic GNSS Correction in Asset Mapping Management (12563)

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## 1.0 INTRODUCTION

GNSS (Global Navigation Satellite System) is a satellite-based navigation system that provides location and time information anywhere on Earth where there is an unobstructed line of sight to four or more GPS satellites. GNSS has become essential in various sectors such as transportation, agriculture, construction, and surveying (Sajid, *et al.* 2022).

In air transportation, GNSS technology has enabled the creation of waypoints without needing to establish a physical infrastructure, thus resulting in increased efficiency and safety. The aviation sector obtains significant economic and environmental benefits from the GNSS technology (Sajid, *et al.* 2022).

GNSS technology has enabled precision farming in agriculture by providing accurate positioning information for tractors and other farm machinery. This allows farmers to optimize their use of fertilizers and pesticides, reduce soil compaction, and increase crop yields (Matteo Luccio, 2021).

GNSS technology has enabled the automation of many construction tasks by providing centimeter-level positioning and high-accuracy orientation of machinery. This takes them one step closer to being performed by autonomous machines (Matteo Luccio, 2021).

In surveying, GNSS technology has enabled surveyors to obtain accurate positioning information for land surveying and mapping. This provides surveyors with a set of practical operational guidelines that can be used when undertaking any survey that includes GNSS techniques (RICS, 2010).

A complete paradigm shift from the previously known conventional ground surveying techniques employed many decades ago in establishing first-order control networks is the innovation brought about due to the advent and utilization of GNSS and CORS. CORS are basically referred to as ground-based or roof-based mounted GNSS infrastructure that can be used to store, process and archive GNSS data useful in several areas of applications (Oladosu, *et al.* 2022).

Many countries are discouraging the ongoing maintenance and development of passive control networks in favor of developing GNSS CORS networks. This is because GNSS CORS networks can provide more accurate positioning information than passive control networks (Blick and Donnelly, 2012).

GNSS CORS (Continuously Operating Reference Station) networks are globally and widely distributed. They are classified as global, regional, national, and local networks based on the covered region. The aim of GNSS CORS networks is to provide accurate positioning information for a wide range of applications (Dardanelli and Specht, 2023).

GNSS CORS supports applications such as infrastructure projects, asset management, resource and emergency management, machine guidance, intelligent transport systems, precision agriculture, and environmental research (Holiday and Suva, 2018).

The foundational step in the management of the earth's resources as well as infrastructural assets is the mapping of the existing asset. This provides the data for monitoring changes in the asset composition over time.

The CORS network can provide technical support and reference for regional planning and geological disaster prevention by quantitatively monitoring the changes in the entire surface of ground deformation and analyzing changes in regional ground stability (Wang *et al*., 2021).

In the monitoring of bridges, high-rise buildings, and dams for deformation control, the precise mapping of the as-is details of the infrastructure during and after construction, as well as the establishment of monitoring control stations would provide the base data. GNSS CORS provides a platform for consistently monitoring changes in the infrastructural position with millimeter precision in dams, bridges, and high-rise buildings (Shi and Wang, 2007).

In this paper, we highlight the requirements for developing a GNSS infrastructure using the Sacredion Online GNSS Positioning Service (SOGPOS) as a case study, a CORS platform established by Sacredion in collaboration and partnership with Nigerian Institution of Surveyors, Association of Private Practicing Surveyors and Tersus GNSS Incorporated. The CORS network provides static GNSS data for post-processing correction and Real Time Kinematic Correction services. Finally, the applications of SOGPOS as a platform for providing precise and accurate dataset for asset monitoring, tracking, and management is presented with some state-based challenges discussed where applicable.

## 1.1 Types of CORS Stations

According to the NOAA, Continuously Operating Reference Stations (CORS) Network (NCN), there are three types of CORS stations: Single CORS station, Multiple CORS stations and Network CORS stations (NOAA, 2023).

Single CORS station is one GNSS reference station that provides data for a specific location. Multiple CORS stations are two or more GNSS reference stations that provide data for a specific area. Network CORS stations are multiple GNSS reference stations that provide data for a large area (geo-matching, 2023).

## 1.2 Principle for Designing CORS Network

Fuyang, *et al*, 2009, identified that the principle for the design of CORS network would determine if the ambiguity can resolve quickly and correctly, and make user to initialize quickly in high accuracy. They highlighted the following principles for the designing of CORS network.

i. Even distribution of CORS stations. It can advance the accuracy of interpolation of the error related to space. At the same time, the even distribution in vertical direction should be considered, especially in large hypsography area, for advancing the accuracy of interpolation of troposphere error.

ii. Reasonable distance between CORS stations. The area controlled by same number of reference stations is larger and the cost is smaller along with longer distance between CORS stations.

iii. Economy benefit. When CORS Network is designed, the different density of CORS stations according to the degree of economy development and the importance of different areas must be taken into account

## 2.0 MATERIAL AND METHOD

In this paper, nine (9) out of twelve (12) CORS of the Sacredion Online GNSS Positioning Services) is presented

## 2.1 The Sacredion Online GNSS Positioning Service (SOGPOS)

SOGPOS is a network of Continuously Operating Reference Stations (CORS). The SOGPOS platform provides real-time kinematic (RTK) correction for GNSS positioning as well as access to Static GNSS data for post-processing. SOGPOS in its present state does not stream RTK correction as a virtual reference service, rather RTK corrections transmission is based on the nearest Station to the rover position.

The Platform at present is a collaborative work between Sacredion Nigeria Limited, Tersus GNSS INC, Association of Private Practicing Surveyors (APPSN) Abia State

(ABIA CORS), Association of Private Practicing Surveyors (APPSN) Osun State (OSUN CORS), and Prof. Ehigiator – Irughe, Raphael - Professor of Geodesy & Geomatics Engineering, Department of Geomatics, University of Benin, Edo State Nigeria (GEOSYSTEM CORS) and the department of surveying and geoinformatics, Federal University of Technology, Minna, Niger State, Nigeria.

The SOGPOS project is in continuous development as we integrate and partner with other Association of Private Practicing Surveyors in Nigeria

## 2.2 Present Locations of SOGPOS CORS Across Nigeria

The table below shows the location of the SOGPOS CORS across Nigeria and the year of establishment.

| CORS NAME | CORS CODE | CORS PLATFORM | CORS ANTENNA TYPE | LONGITUDE (DMS) | LATITUDE (DMS) | CORS PARTNER | LOCATION |
|---|---|---|---|---|---|---|---|
| Abakaliki CORS | ABAK | Concrete Monument at Ground Level | Tersus Choke Ring AX3707 GNSS Antenna | 6 18 54.20016 | 8 07 22.23161 | APPSN Ebonyi State | Abakaliki, Ebonyi State. Established August 2023 |
| Abia CORS | ABIA | Roof Top Extension Installation | Tersus AXE402 GNSS Antenna | 5 31 27.38900 | 7 31 13.13287 | APPSN Abia State | Umuahia, Abia State. Established August, 2021 |
| Asaba CORS | ASAB | Installation on Tank Tower | Tersus Choke Ring AX3707 GNSS Antenna | 6 11 42.01732 | 6 43 08.96198 | APPSN Delta State | Asaba, Delta State. Established July 2023 |
| FutMinna CORS | FUTM | Roof Top Extension Installation | Tersus AXE402 GNSS Antenna | 9 32 05.56194 | 6 27 03.57572 | Department of Surveying and Geoinformatics Federal University of Technology Minna, Niger State | Gidan Kwano Campus, Federal University of Technology Minna. Established August 2023 |
| Geosystem CORS | GEOS | Roof Top Extension Installation | Tersus AXE402 GNSS Antenna | 6 19 51.40498 | 5 38 17.89957 | Prof. Raphael Ehigiator - Irughe | Benin City, Edo State. Established July 2021 |
| Ibadan CORS | IBAD | Roof Top Installation | Tersus Choke Ring AX3707 GNSS Antenna | 7 24 50.82818 | 3 54 48.97744 | NIS and APPSN Oyo State | Ibadan, Oyo State. Established March 2023 |
| Osun CORS | OSUN | Concrete Monument at Ground Level | Tersus AXE402 GNSS Antenna | 7 45 09.94533 | 4 31 32.97861 | APPSN Osun State | Osogbo, Osun State, March 2022 |
| Sacredion CORS | SACR | Roof Top Installation | Tersus AXE402 GNSS Antenna | 6 35 42.74584 | 3 21 09.40101 | Sacredion Nigeria Limited | Ikeja, Lagos State. Established November 2019. |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Warri CORS | WARR | Roof Top Extension Installation | Tersus Choke Ring AX3707 GNSS Antenna | 5 34 02.31112 | 5 48 36.03858 | APPSN Delta State | Warri, Delta State. Established July 2023. |

* APPSN: Association of Private Practicing Surveyors *NIS: Nigerian Institution of Surveyors


Figure1: Locations of SOGPOS CORS (adapted from Google Earth)

### 2.3 Component of the SOGPOS CORS in Each Station

Each of the SOGPOS CORS comprises of Tesus GeoBee CORS with accompanying components.

The Tersus GeoBee30 CORS is a dedicated and cost-effective solution to transmit or receive NTRIP corrections. With Tersus NTRIP Caster Service, NTRIP Modem and David30 GNSS Receiver, the GeoBee30 opens the possibility for users to transmit Real Time Kinematic (RTK) corrections via Internet (Ethernet or 2G/3G/4G) in a simple, user friendly way, just using a SIM card or Ethernet cable without any need of purchasing another static IP as the system has a unique IP address.

The Tersus GeoBee CORS antenna can either be a Choke Ring AX3707 GNSS Antenna or Smart Tersus AXE402 GNSS Antenna

Figure 2: Tersus Smart AXE402 GNSS Antenna, SOGPOS Osun CORS in Osogbo (APPSN Osun State)

Figure 3: SOGPOS Ibadan CORS (Tersus AX3707 Choke Ring Antenna)

Figure 4: SOGPOS Abakaliki CORS Monument (Tersus AX3707 Choke Ring Antenna)

With the  Tersus GeoBee CORS receiver, antenna and router in place, Tersus GNSS provides NTRIP Caster for transmitting RTK correction via Internet Protocol for applications such as surveying, agriculture, UAV, machine control, etc. It is also ideal for deformation monitoring.

The Tersus GeoBee CORS provides all users with NTRIP client login details for connecting to the NTRIP Server which host the Tersus GeoBee CORS.

A desktop computer with large monitor, high speed RAM and large memory was installed to allow uninterrupted operation of the CORS Data centre and the monitoring of Reference Station.

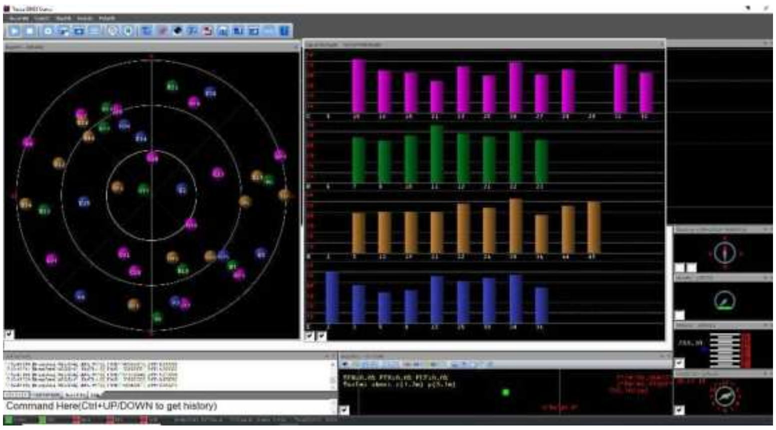



Figure 5: SOGPOS CORS GNSS Positioning Satellites monitoring Status in Tersus GNSS Center

All SOGPOS CORS are alternatively powered with 3 Mono-crystalline Solar panels 150W and a 20Ah pause width modulation charge controller with the solar system connected to with a 2.4Kva Grade Luminous Battery, a 24V Inverter system with a 4mm² fully insulated Armoured cable.

## 2.4 Positioning Capabilities of SOGPOS Platform

SOGPOS provides Real Time Kinematic Correction streaming from each of the station and not on a network based approached. This means accuracy depreciates with increased distance away from the station for RTK operations.

Typically, RTK transmission from the CORS is based on NTRIP (Networked Transport of RTCM via Internet Protocol). The performance and stability of the correction are dependent on the availability of the internet at the location of the GNSS rover receiving the correction. The RTK correction is broadcasted at a radius of about 85km from each CORS location provided there is internet availability with an accuracy of 1-8cm.

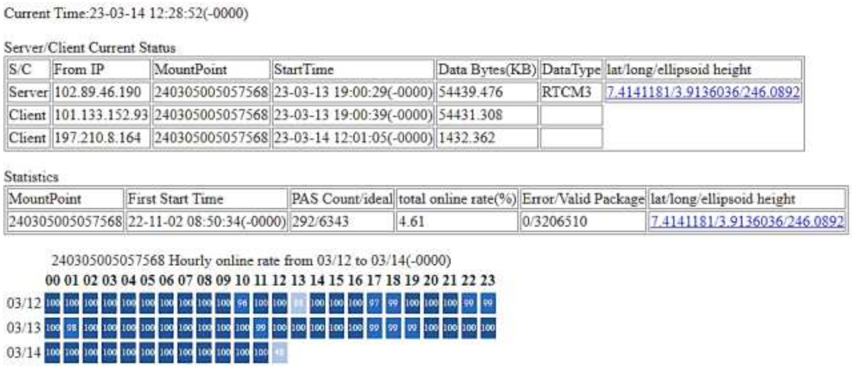
Static observation, which requires post-processing of GNSS data, provides an accuracy of 2-5mm for up to 100km coverage or more, but longer observation time is required for a longer range from the CORS for higher accuracy.

## 2.5 Accessing Real-Time Kinematic Correction and Static GNSS Data from SOGPOS

Each of the SOGPOS CORS are independently managed by the hosting organization. Users' access in the form of the user name and password is provided and managed by the hosting organization.


| Username | Password | ExpiredDate | LimitDays | UsedDays | LimitNums | Current Nums |
|---|---|---|---|---|---|---|
| komolafe | komolafe | | | 0D - 05:24:33 | | 0 |
| damilola | damilola | | | 0D - 00:29:40 | | 0 |
| abiodun | abiodun | | | 0D - 15:57:32 | | 0 |
| victor | victor | | | 0D - 00:00:28 | | 0 |
| abimbola | abimbola | | | 0D - 00:45:39 | | 0 |
| rilwan | rilwan | | | 0D - 00:00:55 | | 0 |
| stephen | stephen | | | 1D - 17:53:26 | | 0 |
| frankadi | frankadi | | | 0D - 00:04:57 | | 0 |
| oluseun | oluseun | | | 0D - 00:00:42 | | 0 |
| abubakar | abubakar | | | 0D - 00:00:40 | | 0 |
| reuben | reuben | | | 0D - 00:13:20 | | 0 |
| michael | michael | | | 0D - 00:00:00 | | 0 |

Figure 6: Web based Interface for management of users of Sacredion CORS



Current Time:23-03-14 12:28:52(-0000)

Server/Client Current Status

| S/C | From IP | MountPoint | StartTime | Data Bytes(KB) | DataType | lat/long/ellipsoid height |
|---|---|---|---|---|---|---|
| Server | 102.89.46.190 | 240305005057568 | 23-03-13 19:00:29(-0000) | 54439.476 | RTCM3 | 7.4141181/3.9136036/246.0892 |
| Client | 101.133.152.93 | 240305005057568 | 23-03-13 19:00:39(-0000) | 54431.308 | | |
| Client | 197.210.8.164 | 240305005057568 | 23-03-14 12:01:05(-0000) | 1432.362 | | |

Statistics

| MountPoint | First Start Time | PAS Count/ideal | total online rate(%) | Error/Valid Package | lat/long/ellipsoid height |
|---|---|---|---|---|---|
| 240305005057568 | 22-11-02 08:50:34(-0000) | 292/6343 | 4.61 | 0/3206510 | 7.4141181/3.9136036/246.0892 |

240305005057568 Hourly online rate from 03/12 to 03/14(-0000)

| | 00 | 01 | 02 | 03 | 04 | 05 | 06 | 07 | 08 | 09 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 03/12 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 96 | 100 | 100 | [illegible] | 100 | 100 | 100 | 97 | 99 | 100 | 100 | 100 | 99 | 99 |
| 03/13 | 100 | 98 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 99 | 100 | 100 | 100 | 100 | 100 | 99 | 99 | 99 | 100 | 100 | 100 | 100 |
| 03/14 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | [illegible] | | | | | | | | | | | |

Figure 7: This shows the online status rate of the SOGPOS CORS

The online status rate indicates when each of the SOGPOS CORS is online and when offline. The reason for being offline could be as a result of power issue at the site location or internet subscription issues. The deep blue indicator represents online status with the date and month indicated.

Furthermore, to access static GNSS data from any of the SOGPOS CORS, all registered users on the platform can download GNSS log files in RINEX format from the SOGPOS online platform via the website at www.sacredioncors.com.

On the website, static data are hosted every 2 hours. This provides easy download of data based on the time of observation and need. The Static data can be queried based on dates and time.

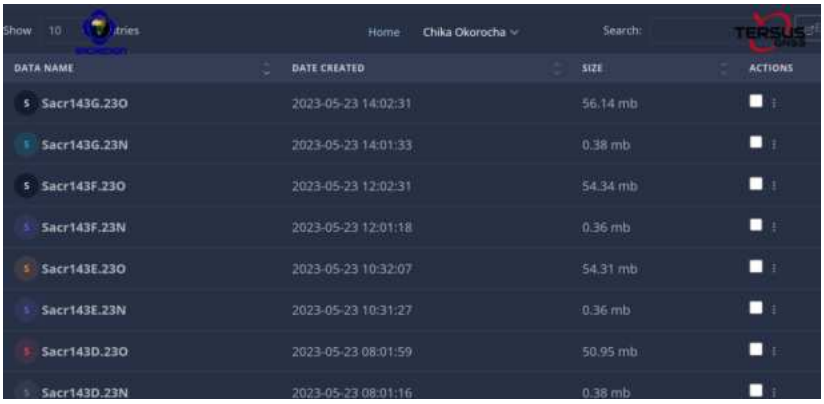



Figure 8: Web-based Interface for downloading static GNSS data from the SOGPOS platform

## 3.0 RESULTS AND DISCUSSION

The result comprises of the processing of the position of the SOGPOS CORS and the discussion would be around the accuracy and applications of the system.

### 3.1 Processing the SOGPOS CORS Location in the International Terrestrial Reference Frame (ITRF)

The AUSPOS Online GPS Processing Service was used for the processing of the final coordinate of the CORS as well as Processing with respect to the existing geodetic reference system in the hosting state. For the purpose of this paper, the processing of Nine of the SOGPOS CORS using AUSPOS is presented.

AUSPOS Online GPS Processing Service uses International GNSS Service (IGS) products (final, rapid, ultra-rapid depending on availability) to compute precise coordinates in International Terrestrial Reference Frame (ITRF) anywhere on Earth and Geocentric Datum of Australia (GDA) within Australia. The Service is designed to process only dual-frequency GPS phase data. AUSPOS provides a network solution (relative positioning) using a double-difference strategy. AUSPOS does not use the Precise Point Positioning (PPP) computation strategy. It makes use of only GPS (Dual-frequency measurements from GPS L1 and L2 signals) out of the CORS GNSS system in the processing. All coordinates' computations are based on the IGS realization of the ITRF2014 reference frame. All the given ITRF2014 coordinates refer to a mean epoch of the site observation data. Geoid-ellipsoidal separations are computed using a spherical harmonic synthesis of the global EGM2008 geoid (AUSPOS, 2023)

AUSPOS uses Bernese GNSS Software Version 5.2 as the computational software for the processing of CORS.

Table 1: SOGPOS data submission to AUSPOS (extracted from AUSPOS report)

| Station (s) | Submitted File | Antenna Type | Antenna Height (m) | Start Time | End Time |
|---|---|---|---|---|---|
| ABAK | ABAK256A_m.230 | TRSAX3706 TRSS | 0.000 | 2023/09/13 00:00:00 | 2023/09/13 21:59:30 |
| ABIA | ABIA256A_m.230 | TRSAX4E02 NONE | 0.000 | 2023/09/13 00:00:00 | 2023/09/13 21:59:30 |
| ASAB | ASAB256A_m.230 | TRSAX3706 TRSS | 0.000 | 2023/09/13 00:00:00 | 2023/09/13 21:59:30 |
| FUTM | FUTm256A_m.230 | TRSAX4E02 NONE | 0.000 | 2023/09/13 00:00:30 | 2023/09/13 21:59:30 |
| GEOS | GEOS256A_m.230 | TRSAX4E02 NONE | 0.000 | 2023/09/13 00:00:00 | 2023/09/13 21:59:30 |
| IBAD | IBAD256A_m.230 | TRSAX3706 TRSS | 0.000 | 2023/09/13 00:00:00 | 2023/09/13 21:59:30 |
| OSUN | OSUN256A_m.230 | TRSAX4E02 NONE | 0.000 | 2023/09/13 00:00:00 | 2023/09/13 21:59:30 |
| SACR | Sacr256A_m.230 | TRSAX4E02 NONE | 0.000 | 2023/09/13 00:00:00 | 2023/09/13 21:59:30 |
| WARR | WARR256A_m.230 | TRSAX3706 TRSS | 0.000 | 2023/09/13 00:00:00 | 2023/09/13 23:59:30 |

Table 2: IGS CORS Utilized in the double difference GNSS processing of SOGPOS CORS (extracted from AUSPOS report)

| Date | User Stations | Reference Stations | Orbit Type |
|---|---|---|---|
| 2023/09/13 00:00:00 | ABAK ABIA ASAB FUTM GEOS IBAD OSUN SACR WARR | ADIS ASCG CPVG DYNG EBRE LPAL MAS1 MAT1 NKLG STHL VILL YEBE | IGS rapid |

Table 3: ITRF2014 Cartesian Coordinate for SOGPOS CORS (extracted from AUSPOS report)

| Station | X (m) | Y (m) | Z (m) | ITRF2014 @ |
|---|---|---|---|---|
| ABAK | 6276158.362 | 895782.552 | 696905.820 | 13/09/2023 |
| ABIA | 6294279.145 | 830928.044 | 609932.862 | 13/09/2023 |
| ASAB | 6297658.645 | 741939.544 | 683708.987 | 13/09/2023 |
| FUTM | 6251040.330 | 706800.505 | 1049594.680 | 13/09/2023 |
| GEOS | 6308936.753 | 622855.365 | 698656.750 | 13/09/2023 |
| IBAD | 6310657.406 | 431722.911 | 817602.063 | 13/09/2023 |
| OSUN | 6300862.625 | 498746.596 | 854742.153 | 13/09/2023 |
| SACR | 6325432.282 | 370550.029 | 727690.873 | 13/09/2023 |
| WARR | 6315674.067 | 642637.657 | 614655.566 | 13/09/2023 |
| ADIS | 4913652.481 | 3945922.879 | 995383.584 | 13/09/2023 |
| ASCG | 6121151.553 | -1563978.978 | -872615.267 | 13/09/2023 |
| CPVG | 5626883.439 | -2380932.279 | 1824484.060 | 13/09/2023 |
| DYNG | 4595220.053 | 2039434.222 | 3912625.885 | 13/09/2023 |
| EBRE | 4833519.939 | 41537.476 | 4147461.773 | 13/09/2023 |
| LPAL | 5326646.215 | -1719825.919 | 3052043.962 | 13/09/2023 |
| MAS1 | 5439192.133 | -1522055.141 | 2953455.133 | 13/09/2023 |
| MAT1 | 4641951.102 | 1393054.016 | 4133281.142 | 13/09/2023 |
| NKLG | 6287385.684 | 1071574.943 | 39133.269 | 13/09/2023 |
| STHL | 6104817.294 | -605827.721 | -1740738.612 | 13/09/2023 |
| VILL | 4849833.522 | -335048.664 | 4116015.175 | 13/09/2023 |
| YEBE | 4848724.529 | -261631.846 | 4123094.392 | 13/09/2023 |

Table 4: ITRF2014 Geodetic Coordinate, GRS80 Ellipsoid for SOGPOS CORS (extracted from AUSPOS report)

| Station | Latitude (DMS) | Longitude (DMS) | Ellipsoidal Height(m) | Derived Above Geoid Height(m) |
|---|---|---|---|---|
| ABAK | 6 18 54.20016 | 8 07 22.23161 | 71.297 | 49.661 |
| ABIA | 5 31 27.38900 | 7 31 13.13287 | 179.127 | 159.172 |
| ASAB | 6 11 42.01732 | 6 43 08.96198 | 74.903 | 54.686 |
| FUTM | 9 32 05.56194 | 6 27 03.57572 | 275.451 | 249.352 |
| GEOS | 6 19 51.40498 | 5 38 17.89957 | 110.615 | 91.039 |
| IBAD | 7 24 50.82818 | 3 54 48.97744 | 245.216 | 219.793 |
| OSUN | 7 45 09.94533 | 4 31 32.97861 | 352.291 | 326.622 |
| SACR | 6 35 42.74584 | 3 21 09.40101 | 68.362 | 45.254 |
| WARR | 5 34 02.31112 | 5 48 36.03858 | 34.346 | 16.177 |
| ADIS | 9 02 06.49714 | 38 45 58.70541 | 2439.102 | 2446.161 |
| ASCG | -7 54 58.60876 | -14 19 57.59381 | 37.958 | 23.009 |
| CPVG | 16 43 55.42975 | -22 56 05.75162 | 94.067 | 63.285 |
| DYNG | 38 04 42.78722 | 23 55 56.76716 | 510.570 | 471.284 |
| EBRE | 40 49 15.20723 | 0 29 32.51953 | 107.790 | 57.605 |
| LPAL | 28 45 49.94785 | -17 53 37.77039 | 2199.189 | 2155.282 |
| MAS1 | 27 45 49.47948 | -15 37 59.78126 | 197.128 | 153.590 |
| MAT1 | 40 38 56.63516 | 16 42 16.38514 | 534.528 | 489.025 |
| NKLG | 0 21 14.07523 | 9 40 19.66336 | 31.494 | 21.508 |
| STHL | -15 56 33.11442 | -5 40 02.43446 | 453.182 | 436.521 |
| VILL | 40 26 36.94602 | -3 57 07.11041 | 647.351 | 595.401 |
| YEBE | 40 31 29.65207 | -3 05 19.03932 | 972.765 | 920.264 |

Table 5: ITRF2014 UTM GRID Coordinate, GRS80 Ellipsoid for SOGPOS CORS (extracted from AUSPOS report)

| Station | East (m) | North (m) | Zone | Ellipsoidal Height (m) | Derived Above Geoid Height(m) |
|---|---|---|---|---|---|
| ABAK | 402978.900 | 698113.396 | 32 | 71.297 | 49.661 |
| ABIA | 336089.709 | 610821.092 | 32 | 179.127 | 159.172 |
| ASAB | 247605.890 | 685303.236 | 32 | 74.903 | 54.686 |
| FUTM | 220164.340 | 1055019.331 | 32 | 275.451 | 249.352 |
| GEOS | 791900.188 | 700529.745 | 31 | 110.615 | 91.039 |
| IBAD | 600821.172 | 819632.419 | 31 | 245.216 | 219.793 |
| OSUN | 668263.979 | 857267.828 | 31 | 352.291 | 326.622 |
| SACR | 538979.127 | 729014.576 | 31 | 68.362 | 45.254 |
| WARR | 811341.999 | 616115.425 | 31 | 34.346 | 16.177 |
| ADIS | 474316.292 | 998745.176 | 37 | 2439.102 | 2446.161 |
| ASCG | 573556.316 | 9124898.484 | 28 | 37.958 | 23.009 |
| CPVG | 293716.331 | 1850918.060 | 27 | 94.067 | 63.285 |
| DYNG | 757212.240 | 4218592.068 | 34 | 510.570 | 471.284 |
| EBRE | 288524.374 | 4521900.763 | 31 | 107.790 | 57.605 |
| LPAL | 217438.490 | 3185260.931 | 28 | 2199.189 | 2155.282 |
| MAS1 | 437599.047 | 3071192.210 | 28 | 197.128 | 153.590 |
| MAT1 | 644116.295 | 4501197.875 | 33 | 534.528 | 489.025 |
| NKLG | 574791.407 | 39120.380 | 32 | 31.494 | 21.508 |
| STHL | 214447.180 | 8235594.770 | 30 | 453.182 | 436.521 |
| VILL | 419267.362 | 4477429.039 | 30 | 647.351 | 595.401 |
| YEBE | 492493.490 | 4486022.778 | 30 | 972.765 | 920.264 |

Table 6: Positional Uncertainty (95% C.L.) - Geodetic, ITRF2014 for SOGPOS CORS (extracted from AUSPOS report)

| Station | Longitude(East) (m) | Latitude(North) (m) | Ellipsoidal Height(Up) (m) |
|---|---|---|---|
| ABAK | 0.007 | 0.005 | 0.014 |
| ABIA | 0.007 | 0.005 | 0.013 |
| ASAB | 0.006 | 0.005 | 0.012 |
| FUTM | 0.009 | 0.006 | 0.023 |
| GEOS | 0.006 | 0.005 | 0.013 |
| IBAD | 0.006 | 0.005 | 0.012 |
| OSUN | 0.006 | 0.005 | 0.013 |
| SACR | 0.006 | 0.005 | 0.011 |
| WARR | 0.006 | 0.005 | 0.011 |
| ADIS | 0.008 | 0.005 | 0.015 |
| ASCG | 0.006 | 0.005 | 0.012 |
| CPVG | 0.007 | 0.005 | 0.016 |
| DYNG | 0.006 | 0.005 | 0.010 |
| EBRE | 0.006 | 0.004 | 0.008 |
| LPAL | 0.006 | 0.004 | 0.010 |
| MAS1 | 0.006 | 0.004 | 0.009 |
| MAT1 | 0.006 | 0.005 | 0.010 |
| NKLG | 0.006 | 0.004 | 0.009 |
| STHL | 0.006 | 0.005 | 0.010 |
| VILL | 0.006 | 0.005 | 0.011 |
| YEBE | 0.006 | 0.005 | 0.010 |

Table 7: Ambiguity Resolution - Per Baseline for SOGPOS CORS (extracted from AUSPOS report)

| Baseline | Ambiguities Resolved | Baseline Length (km) |
|---|---|---|
| LPAL - MAS1 | 72.3 % | 247.991 |
| ABAK - ASAB | 45.1 % | 155.898 |
| OSUN - IBAD | 63.7 % | 77.250 |
| WARR - GEOS | 41.5 % | 86.562 |
| EBRE - YEBE | 77.8 % | 304.527 |
| DYNG - MAT1 | 73.9 % | 684.602 |
| EBRE - MAS1 | 19.6 % | 2058.473 |
| NKLG - SACR | 68.2 % | 983.359 |
| VILL - YEBE | 87.9 % | 73.766 |
| NKLG - WARR | 51.3 % | 718.341 |
| CPVG - MAS1 | 86.0 % | 1430.900 |
| WARR - ASAB | 38.7 % | 122.286 |
| NKLG - STHL | 27.6 % | 2452.540 |
| SACR - IBAD | 50.5 % | 109.747 |
| ABIA - ASAB | 60.2 % | 115.643 |
| ADIS - DYNG | 23.3 % | 3499.486 |
| FUTM - ASAB | 57.3 % | 370.514 |
| ASCG - STHL | 71.2 % | 1293.042 |
| EBRE - MAT1 | 57.2 % | 1365.100 |
| MAS1 - NKLG | 70.8 % | 3992.446 |
| AVERAGE | 57.2% | 1007.124 |

From the foregoing result presentation, it can be seen that the result of the CORS station are reliable as the average ambiguity resolutions for all baselines is above 50% success rate. The geodetic Coordinates of the SOGPOS CORS have a positional uncertainly of 5-9mm in longitude and latitude and 1-2cm in ellipsoidal height at 95% confidence level, which means surveying activities carried out with reference to the CORS would provide reliable results in positioning.

The SOGPOS CORS thus has the advantage of solving the problem of identifying passive controls in any of the locations where they are not located providing reliable Real Time kinematic correction for users as well as static GNSS data for post-processing.

The major disadvantage of the Real-Time correction service of SOGPOS is the dependency on reliable internet connectivity, as such areas with a poor internet connection would have limited access to the correction transmission from the CORS.

## 3.2 Application Areas of SOGPOS CORS in Asset Monitoring and Management for Economic Enhancement

The applications of GNSS CORS infrastructure cuts across different areas of construction, mapping, asset management, and deformation monitoring across different industries. Some of the applications are:

### 3.2.1 City Development and Management

The CORS system is used in digital cities development and management for urban geospatial framework construction, urban geoid refinement, and urban spatial data collection (Xiang-don, 2012). The development of new cities requires highly effective planning and design. The city design would then be implemented physically on the ground with the best possible accuracy. CORS network provides a platform that would ensure homogeneity of design implementation.

Passive controls were usually associated with displacement and sometimes total destruction, but with the SOGPOS CORS network, the design implementation can be carried out with GNSS receivers in Real Time Kinematic Mode at ease with no limitation to the number of receivers that can connect to the CORS. This would ensure the land resources of a cosmopolitan city like Lagos with high pressure on land use are properly managed and effectively tracked against non-conformity with the city design.

### 3.2.2 Geological, Mining, and Exploration of Mineral Resources

In the investigation and exploration of resources, CORS can provide higher accuracy and stronger integrated application than conventional techniques. CORS combined with Remote Sensing and Geographic Information System (GIS) can provide geochemical data for prospecting and basic geological study (Shi and Wang, 2007).

CORS technology offers unique advantages across a range of activities in mining, including seismic line surveys, reclamation deformation monitoring, volume calculations, GNSS-controlled machine guidance systems and photogrammetry and Lidar applications where static GNSS data is required (Said *et al., 2023*).

### 3.2.3 Deformation Monitoring of Dam, Bridges and Highrise Buildings

GNSS CORS can be used for deformation monitoring of buildings by measuring the position of the building over time. This technique is called GNSS-based Structural Health Monitoring (SHM) (Drummond, 2010) . It is a non-destructive method that can detect structural changes in buildings over time. The technique can be used to monitor the deformation of buildings and bridges providing very high level of structural movement at a millimeter level when combined with sensors. This study has become very necessary with the increase in the number of building collapse in Lagos.

### 3.2.4 Natural Disaster Monitoring, Prediction and Prevention

The applications of GNSS CORS network is very effective in natural disaster monitoring such as earth quake, and landslides. The technique involves the use of GNSS receivers that are installed on stable monuments and continuously record data on the position of the monument. The data is then processed to determine any changes in position over time. This technique is used to monitor ground deformation caused by natural or man-made factors such as earthquakes, landslides, subsidence, and mining activities (Ohta and Ohzono 2022)

### 3.3.5 Weather Forecasting

The GNSS signals are affected by the ionosphere, which can cause delays and phase shifts in the signals. These delays and phase shifts can be used to estimate the total electron content (TEC) of the ionosphere. TEC is an important parameter for weather forecasting because it affects the propagation of radio waves through the ionosphere (Wilgan *et al,* 2023).

TEC can be estimated across the SOGPOS CORS network which would form the bases for atmospheric research and weather forecasting. This study is of immense importance as there had been several flooding menaces in Nigeria.

## 4.0 CONCLUSION AND RECOMMENDATIONS

The SOGPOS platform developed by Sacredion in collaboration with partnering organizations has been found to be a very reliable source of GNSS correction for the replacement of passive control network. The CORS has the advantage of covering about 85km radius provided there is a reliable internet connection with the option of access to static GNSS data for post-processing. The sustainability of such a platform will require constant usage, adequate power supply, and regular internet subscription.

The system will make surveying activities more cost-effective and increase safety with the exclusion of conventional base stations. The platform has the potential to advance more research in the area of GNSS positioning for both academic and government institutions with applications not just in conventional surveying and mapping but in large-scale city planning and asset management, deformation monitoring of dams, bridges and high-rise buildings, natural disaster forecasting, monitoring, and management.

The advantages of CORS network applications are enormous, and we hope that this paper will trigger more research and industry-based applications in solving real-life problems towards achieving sustainable development goals.

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