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

Chika Vincent OKOROCHA and Raphael Irughe EHIGIATOR (Nigeria)

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 and 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).

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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.

The Applications of Sacredion Online GNSS Positioning Service (SOGPOS) for Real-Time Kinematic GNSS Correction in Asset Mapping and Management (12563)
Okorocha Chika and Raphael Ehigiator (Nigeria)

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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

The Applications of Sacredion Online GNSS Positioning Service (SOGPOS) for Real-Time Kinematic GNSS Correction in Asset Mapping and Management (12563)
Okorocha Chika and Raphael Ehigiator (Nigeria)

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Accra, Ghana, 19–24 May 2024

(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.

The Applications of Sacredion Online GNSS Positioning Service (SOGPOS) for Real-Time Kinematic GNSS Correction in Asset Mapping and Management (12563)
Okorocha Chika and Raphael Ehigiator (Nigeria)

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

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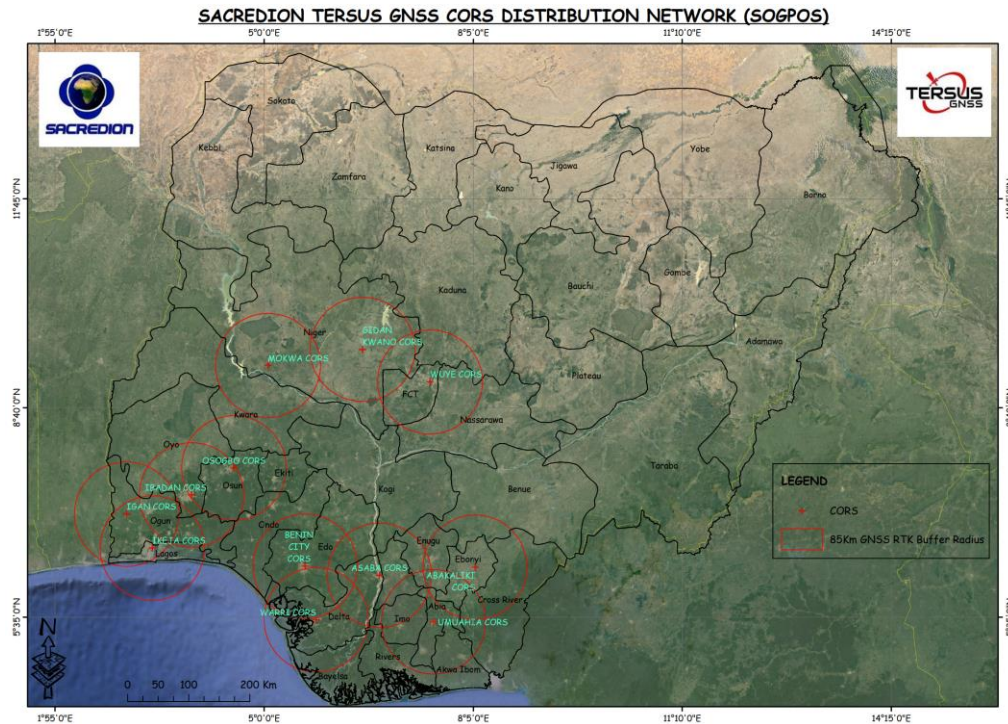

Figure1: Locations of SOGPOS CORS (adapted from Google Earth)

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

The Applications of Sacredion Online GNSS Positioning Service (SOGPOS) for Real-Time Kinematic GNSS
Correction in Asset Mapping and Management (12563)
Okorocha Chika and Raphael Ehigiator (Nigeria)

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Accra, Ghana, 19–24 May 2024

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)

The Applications of Sacredion Online GNSS Positioning Service (SOGPOS) for Real-Time Kinematic GNSS Correction in Asset Mapping and Management (12563)
Okorocha Chika and Raphael Ehigiator (Nigeria)

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Accra, Ghana, 19–24 May 2024

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.

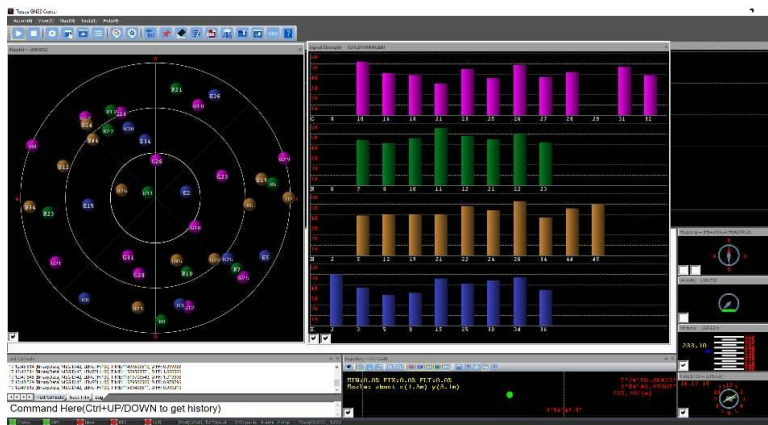Figure 5: SOGPOS CORS GNSS Positioning Satellites monitoring Status in Tersus GNSS Center

The Applications of Sacredion Online GNSS Positioning Service (SOGPOS) for Real-Time Kinematic GNSS Correction in Asset Mapping and Management (12563)
Okorocha Chika and Raphael Ehigiator (Nigeria)

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Accra, Ghana, 19–24 May 2024

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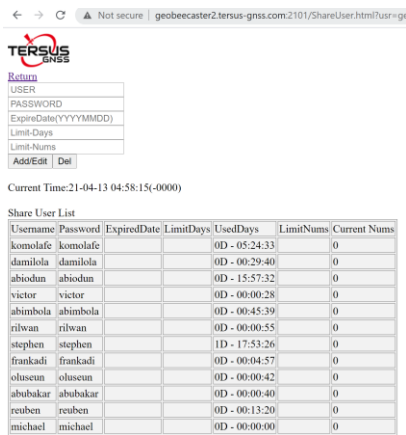
Figure 6: Web based Interface for management of users of Sacredion CORS

The Applications of Sacredion Online GNSS Positioning Service (SOGPOS) for Real-Time Kinematic GNSS Correction in Asset Mapping and Management (12563)
Okorocha Chika and Raphael Ehigiator (Nigeria)

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Accra, Ghana, 19–24 May 2024

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 96 100 100 88 100 100 100 97 99 100 100 100 99 99

03/13 100 98 100 100 100 100 100 100 100 99 100 100 100 100 99 99 100 100 100 100 99

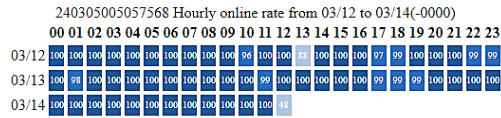03/14 100 100 100 100 100 100 100 100 100 100 100 48

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.

DATA NAME	DATE CREATED	SIZE	ACTIONS
S Sacr143G.23O	2023-05-23 14:02:31	56.14 mb	☐ ⋮
S Sacr143G.23N	2023-05-23 14:01:33	0.38 mb	☐ ⋮
S Sacr143F.23O	2023-05-23 12:02:31	54.34 mb	☐ ⋮
S Sacr143F.23N	2023-05-23 12:01:18	0.36 mb	☐ ⋮
S Sacr143E.23O	2023-05-23 10:32:07	54.31 mb	☐ ⋮
S Sacr143E.23N	2023-05-23 10:31:27	0.36 mb	☐ ⋮
S Sacr143D.23O	2023-05-23 08:01:59	50.95 mb	☐ ⋮
S Sacr143D.23N	2023-05-23 08:01:16	0.38 mb	☐ ⋮
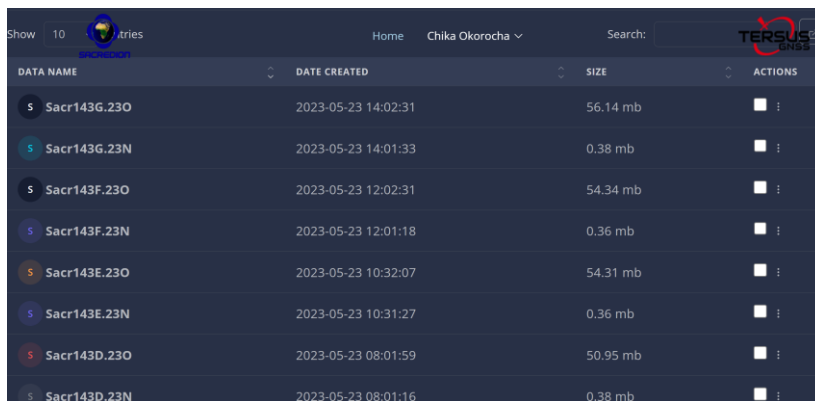
Figure 8: Web-based Interface for downloading static GNSS data from the SOGPOS platform

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.

The Applications of Sacredion Online GNSS Positioning Service (SOGPOS) for Real-Time Kinematic GNSS Correction in Asset Mapping and Management (12563)
Okorocha Chika and Raphael Ehigiator (Nigeria)

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Accra, Ghana, 19–24 May 2024

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

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Okorocha Chika and Raphael Ehigiator (Nigeria)

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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

The Applications of Sacredion Online GNSS Positioning Service (SOGPOS) for Real-Time Kinematic GNSS Correction in Asset Mapping and Management (12563)
Okorocha Chika and Raphael Ehigiator (Nigeria)

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Accra, Ghana, 19–24 May 2024

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)

The Applications of Sacredion Online GNSS Positioning Service (SOGPOS) for Real-Time Kinematic GNSS Correction in Asset Mapping and Management (12563)
Okorocha Chika and Raphael Ehigiator (Nigeria)

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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)

The Applications of Sacredion Online GNSS Positioning Service (SOGPOS) for Real-Time Kinematic GNSS Correction in Asset Mapping and Management (12563)
Okorocha Chika and Raphael Ehigiator (Nigeria)

FIG Working Week 2024
Your World, Our World: Resilient Environment and Sustainable Resource Management for all
Accra, Ghana, 19–24 May 2024

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

The Applications of Sacredion Online GNSS Positioning Service (SOGPOS) for Real-Time Kinematic GNSS Correction in Asset Mapping and Management (12563)
Okorocha Chika and Raphael Ehigiator (Nigeria)

FIG Working Week 2024
Your World, Our World: Resilient Environment and Sustainable Resource Management for all
Accra, Ghana, 19–24 May 2024

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 Applications of Sacredion Online GNSS Positioning Service (SOGPOS) for Real-Time Kinematic GNSS Correction in Asset Mapping and Management (12563)
Okorocha Chika and Raphael Ehigiator (Nigeria)

FIG Working Week 2024
Your World, Our World: Resilient Environment and Sustainable Resource Management for all
Accra, Ghana, 19–24 May 2024

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

The Applications of Sacredion Online GNSS Positioning Service (SOGPOS) for Real-Time Kinematic GNSS
Correction in Asset Mapping and Management (12563)
Okorocha Chika and Raphael Ehigiator (Nigeria)

FIG Working Week 2024
Your World, Our World: Resilient Environment and Sustainable Resource Management for all
Accra, Ghana, 19–24 May 2024

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 Applications of Sacredion Online GNSS Positioning Service (SOGPOS) for Real-Time Kinematic GNSS Correction in Asset Mapping and Management (12563)
Okorocha Chika and Raphael Ehigiator (Nigeria)

FIG Working Week 2024
Your World, Our World: Resilient Environment and Sustainable Resource Management for all
Accra, Ghana, 19–24 May 2024

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.

The Applications of Sacredion Online GNSS Positioning Service (SOGPOS) for Real-Time Kinematic GNSS Correction in Asset Mapping and Management (12563)
Okorocha Chika and Raphael Ehigiator (Nigeria)

FIG Working Week 2024
Your World, Our World: Resilient Environment and Sustainable Resource Management for all
Accra, Ghana, 19–24 May 2024

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The Applications of Sacredion Online GNSS Positioning Service (SOGPOS) for Real-Time Kinematic GNSS Correction in Asset Mapping and Management (12563)
Okorocha Chika and Raphael Ehigiator (Nigeria)

FIG Working Week 2024
Your World, Our World: Resilient Environment and Sustainable Resource Management for all
Accra, Ghana, 19–24 May 2024

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The Applications of Sacredion Online GNSS Positioning Service (SOGPOS) for Real-Time Kinematic GNSS Correction in Asset Mapping and Management (12563)
Okorocha Chika and Raphael Ehigiator (Nigeria)

FIG Working Week 2024
Your World, Our World: Resilient Environment and Sustainable Resource Management for all
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The Applications of Sacredion Online GNSS Positioning Service (SOGPOS) for Real-Time Kinematic GNSS
Correction in Asset Mapping and Management (12563)
Okorocha Chika and Raphael Ehigiator (Nigeria)

FIG Working Week 2024
Your World, Our World: Resilient Environment and Sustainable Resource Management for all
Accra, Ghana, 19–24 May 2024