GNSS CORS TECHNOLOGY IMPLEMENTATION IN THE OIL AND GAS INDUSTRY

BENEFITS AND CHALLENGES

Mpakaboari Opkins EREKOSIMA, Nigeria - Benjamin Edewoh ONORIODE, Nigeria.

Key words: GNSS CORS, Implementation, Benefits, Challenges

ABSTRACT

Continuous Operating Reference Stations (CORS) use the Global Navigation Satellite Systems (GNSS) technology to provide precise spatial positioning, data harmonisation, and enables geodetic data integrity assurance with real-time data streaming and management in a network mode using a specialized software to extend the data coverage and enable real-time field crew monitoring.

Usually, most survey activities in Nigeria are executed using conventional methods which require extensive control search and in-situ checks in often difficult terrains with significant costs and serious health, safety, security and environmental (HSSE) exposures. Some of these surveys are prone to inter-fields coordinate inconsistences especially due to discrepancies in control origins, hence, a compelling reason to deploy the CORS technology to address these issues. Following a careful site selection process, stations were established, configured to acquire, process and transmit differential corrections on a continuous basis to reference survey projects within the Niger Delta. This technology has been leveraged within the Nigeria oil and gas industry to establish primary (geodetic) control pillars, carry out As-built surveys and large-scale seismic acquisition project with significant cost savings and reduced HSSE exposure. The deployment has also enabled geodetic data integrity, data harmonization, and reduced turnaround time, which has eased project delivery within the difficult terrain of the Niger Delta. The implementation of CORS technology obviously is a game changer in survey service delivery within the oil and gas industry, and it is recommended that it should be extended to developing Land Information System speedily throughout Nigeria as a cost effective, quick and accurate channel to update Nigeria utility infrastructure.

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1.0 OVERVIEW

Traditionally, most survey activities in the Nigeria Oil and Gas industries are executed using conventional methods involving the use of Theodolites and Total stations which require extensive control pillar search and in-situ checks in often difficult terrain, with significant costs and serious Health, Safety, Security and Environment (HSSE) exposures. Also, projects executed with conventional methods are prone to coordinate inconsistences across oil and gas fields, due to discrepancies in control origins. Hence, the need to re-strategize and deploy the **C**ontinuously **O**perating **R**eference **S**tation (CORS) based on GNSS technology to address these issues.

These permanent, unmanned, automated and highly precise reference stations (standalone or networked) continuously logs and store GNSS data to provide precise spatial positioning, data harmonisation that enables assured geodetic data integrity.

Generally, to improve positional accuracies of GNSS observations to sub centimeters, a relative positioning technique is employed. Relative GNSS positioning involves the collection of observables by a GNSS reference station whose position is known. These data are then combined with data collected by other receivers, whose positions are to be determined. This process may be performed real-time where corrections are applied instantaneously or in a post-processed mode with relative positioning accuracy in sub-centimetre. If performed in real-time for navigation purposes, the technique is generally known as differential GNSS . Differential involves the

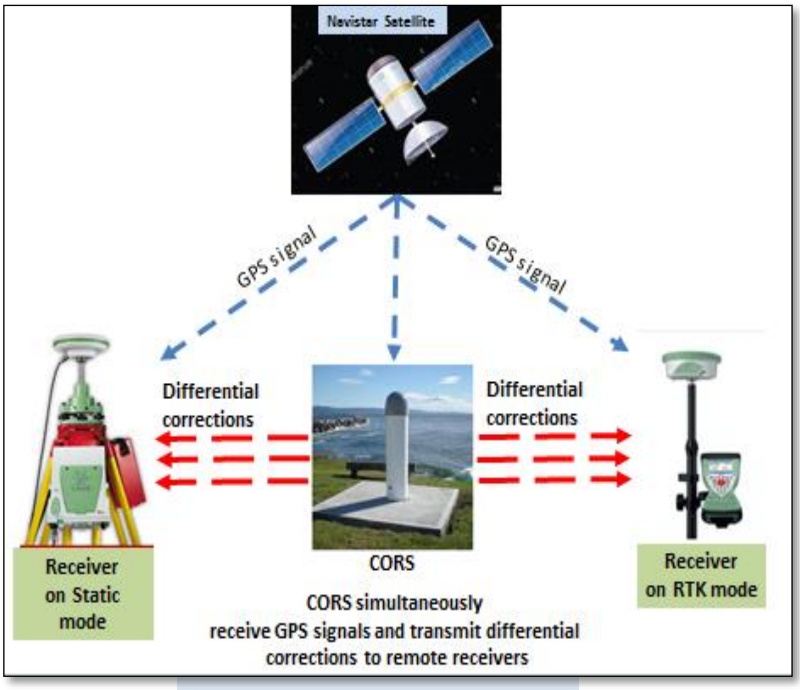

Figure 1: Typical CORS setup

generation and transmission to users of reference station correction data. The equipment and procedures utilized in a relative positioning technique, determines the level of accuracy achievable [**William A. Stone,** (2017, March 22)]. In a typical CORS setup, the differential connection between the individual rover and the CORS station is maintained via radio, internet and GSM communication protocol, providing flexibility during operations and very high accuracies. The Network solution uses the internet protocol mainly for transmitting corrections to rover units.

1.1 AIM

The aim of the project is to establish GNSS CORS in area of interest (AOI) within Niger Delta region of Nigeria.

1.2 OBJECTIVES

- To establish a robust platform for coordinate reference system
- To promote improved data integrity.
- To reduce personnel exposure.
- To enhance project turnaround time.

2.0 METHODOLOGY

Robust planning is a critical success factor in any project. It must cover end-to-end the different aspects of the implementation. For the stations installed within the Niger Delta area, stakeholders' engagements were held to agree on deployment strategies and objectives, design requirements, site identification and selection, equipment selection and installation among other things to guarantee successful deployment.

2.1 Deployment Strategy

The deployment plan focused on issues such as operational coverage or areas of interest (AOI), projected activities, design scope (standalone or network), available financial resources, data storage and management technique.

Operational coverage and AOI: Most operations of the Oil and Gas companies revolve around OMLs, fields, concessions, prospect areas, locations of existing facilities and installations such as flow stations, manifolds, gas plants, logistic bases, pipelines and wells. As part of the deployment strategy, the operational extent or footprint was properly scoped to determine the number of stations required.

CORS Network design: For a standalone CORS, a radio RTK device can cover a range of about 15km depending on the radio specification. The system can also be used in a Dial-up RTK mode, provided the roving unit can connect with the base station. However, there is degradation with respect to accuracy as the rover moves farther away from the base. Manufacturers advise a range of 50km but in application within the oil and gas industry locally, this is further reduced to 30km to guarantee reliable results. With networked stations, a coverage

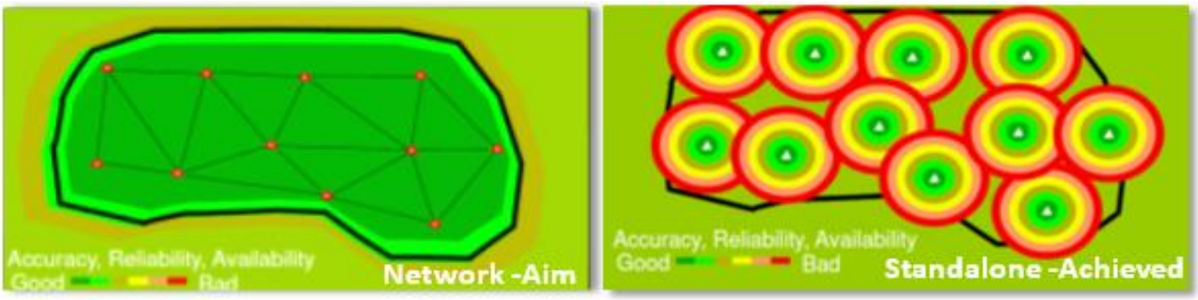

Figure 2: CORS Network and Standalone configuration (GeoQinetiq Implementation Report)

of about 70km is achievable. A suitable network design increases the range of reach and coverage area for the rover units. However, areas of interest need to be within the specified range for the benefits of the CORS to be realized [**Juliet Ezechie,** (October 2014)].

The most fundamental infrastructure required for a networked system is internet access. Presently, a number of options are being explored including VSAT and local telecoms internet providers to fully optimize on the CORS network. A fully functional CORS Network uses

multiple reference stations in a network for GNSS corrections to model and correct for distance-dependent errors that reduce the accuracy of traditional RTK or D positions in proportion to the distance from a rover to its nearest reference station. **[Leica SpiderNET,** (June, 2005)].

The CORS Network implementation has progressed as designed but to be activated mainly due to internet connectivity issues that are yet to be resolved.

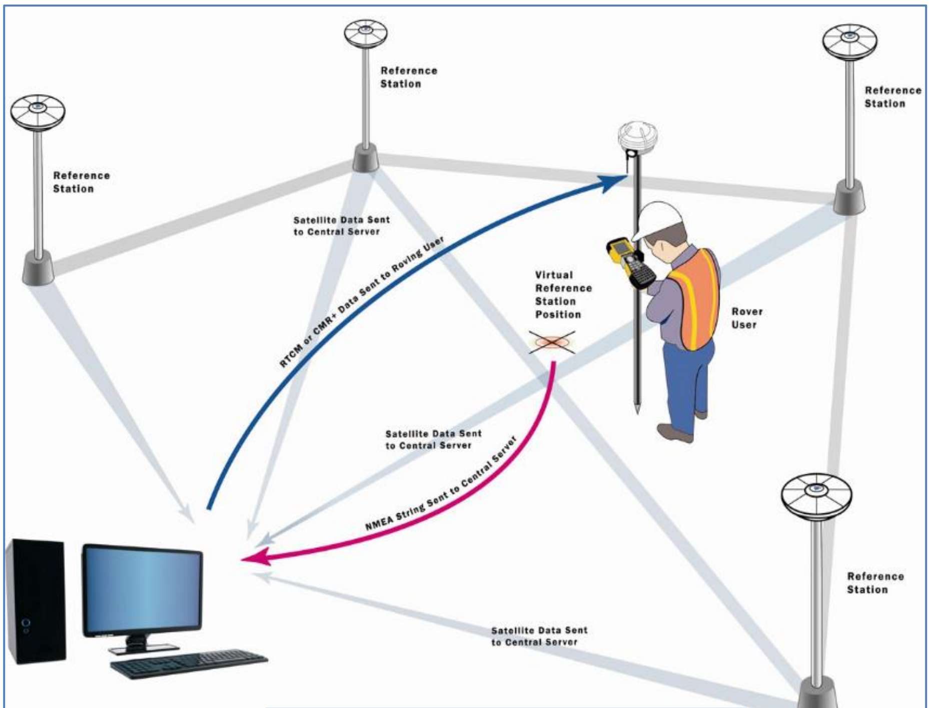

Figure 3: Image Courtesy of Trimble

The benefits of the Networked RTK includes the following:

- The integrity of every reference station in the network is monitored automatically and continuously for consistent accuracy and precision.
- Failure of a reference station on the Network does not affect or halt the activity, efficiency & performance of the entire network or the ongoing survey being carried out.
- The NRTK reference stations allow for network atmospheric modelling resulting in improved accuracy. With RTK, atmospheric effects are computed using (usually) one location. [**United States Geological Survey, USGS** (February 2016)]

Data storage and management: Adequate provision was made for easy data retrieval and adequate storage to prevent data loss. The CORS should be able to provide live and redundant data for extensive analysis and processing. Additionally, provisions should be made for capable software for seamless data management. For instance, Real-time data streaming and management in a network mode can be managed with software such as Leica GNSS Spider software.

2.2 Site Selection

The site selection is paramount to a successful deployment. Sites are selected based on the International GNSS Service (IGS) criteria. IGS which contributes to the realization of the International Terrestrial Reference Frame provides highly accurate GNSS dataset used for a wide range of applications such as navigation, mapping, and spatial positioning to research works. During site selection, a number of proposed sites are tested via a trial logging operation for optimization. Site selection criteria are as follow:

2.2.1 Sky visibility - Visibility to clear sky is a major factor to consider when situating a GNSS CORS. It must be installed where future development will at no time prevent good antenna sky view [**Juliet Ezechie,** (October 2014)].

2.2.2 Error avoidance: Reflective surfaces cause multipath effect with respect to signals. Multipath in turn gives rise to cycle slips. Cycle slips are fixed and ambiguities resolved using:

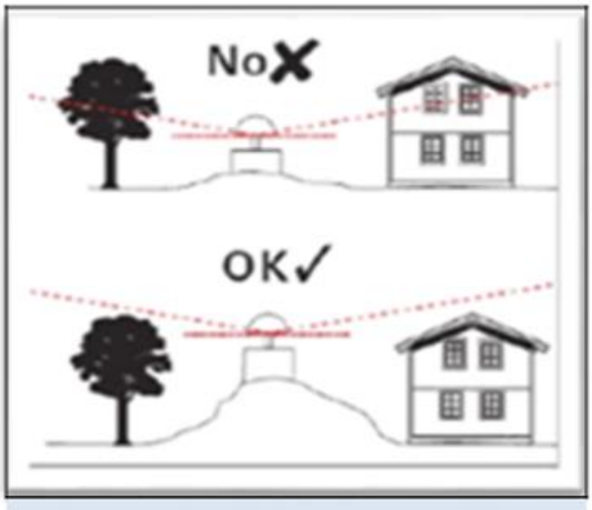

Figure 4: Avoiding Multipath (GeoQinetiq Implementation report)

- Single frequency phase data and
- Linear combination of L1 and L2 { $\mathbf{L5} = \frac{1}{\mathbf{f1-f2}}(\mathbf{f1L1} - \mathbf{f2L2})$}
- Linear combination of both carrier phase and code observables {$\mathbf{L6} = \frac{1}{\mathbf{f1-f2}}(\mathbf{f1L1} - \mathbf{f2L2}) - \frac{1}{\mathbf{f1 \pm f2}}(\mathbf{f1P1} \pm \mathbf{f2LP2})$}. Where f1 and f2 carrier frequency, L1, L2 the signal codes and P1, P2 Code measurements [**Error sources,** (2017, March 22)].

Given the effects of these errors and others, stations should be sited as far away as possible from reflective surfaces like roof sheets, glass walled houses, etc. Also, nearness to micro wave station (say <200m) should be avoided [**Ian Poole,** (2017, March 23)].

2.2.3 Choice of Antenna Monument: The permanence of the monument is essential. This also includes anticipated future development around the station in terms of high rise building spring-up; nearness to installed microwave equipment will likely interrupt workings of GNSS CORS when installed. Mostly, the wall mounted monument is adopted as it is best suited for buildings. However, only a properly designed and well-constructed building should be used for the reasons of stability [**Juliet Ezechie,** (October 2014)].

2.2.4 Availability of power: The station needs to be operational 24/7 which is hinged on availability of constant power supply. Where this is not available, provision should be made for alternate power supply which may eventually add to the installation/running cost of the station.

2.2.5 Communication: GSM signal availability around the station location and internet are invaluable for smooth running of the station.

2.2.6 Security: Lack of adequate security may lead to hardware loss and interference by third party. The station should be situated in a controlled environment, but with easy access for maintenance and optimization.

2.3 Equipment Selection

Equipment (Antennae type, GNSS Receiver) choice is an important factor to consider. For instance, the use of the choke ring antenna is advised due to its ability to handle the effects of multipath [**GIS Integration,** (March 20, 2017)]. It also provides accuracy, quality, ruggedness and ability to endure extreme weather conditions among others. Suitable communication devices such radio, GSM and internet units need to be carefully evaluated prior selection [**Juliet Ezechie,** (October 2014)].

Figure 5: Hardware selection (GeoQinetiq Implementation report)

2.4 Installation

Once the optimal site has been identified and suitable equipment selected, installation then follows. Below are the installation steps:

2.4.1 Site preparation**-** First, the monument is installed according to design on the selected structure. The antenna is affixed to the monument and checked for firmness and stability. The antenna height is measured and used during station configuration.

2.4.2 Installation of cabinet and station modules:

The cabinet is either fastened to the wall of the CORS room or placed on the ground for housing the receiver. The selected GNSS Receiver, GNSS Antenna, Radio, GSM modem, and GNSS Antenna Cable are installed.

Figure 6: Station modules

2.4.3 Station Configuration:

Information such as station name, antenna height, radio operating frequencies, internet protocols, dial up details, data log rate, elevation mask, data exchange formats are configured on the station and then activated via the receiver's web interface.

2.4.4 Assurance:

Precise positioning is a key requirement for a GNSS CORS implementation**.** Consequently, observations and results are subjected to series of tests and checks for assurance before final adoption.

It is required to conduct continuous data logging (3-7days) and analysis for quality assurance for each station. Logged data was then processed using Leica Geo office v8.3 and Bernese software to achieve optimal accuracy. Also, observation results were checked on known available local geodetic controls using RTK – Real Time to assure position coordinates. [**Juliet Ezechie,** (October 2014)].

2.4.5 Validation and Publishing

Independent Position QA/QC check by AUSPOS [**AUSPOS,** (2017, March 24)] was carried out before publication of final station coordinates. It uses the International GNSS Services (IGS) products (final, rapid, ultra-rapid depending on availability) to compute precise coordinates in International Terrestrial Reference Frame (ITRF) and Geocentric Datum of Australia 1994 (GDA94) using data collected from other CORS stations and around the earth [**International GNSS services (IGS),** (2004)]. This service is designed to process only dual frequency. phase data. AUSPOS data processing requirement includes:

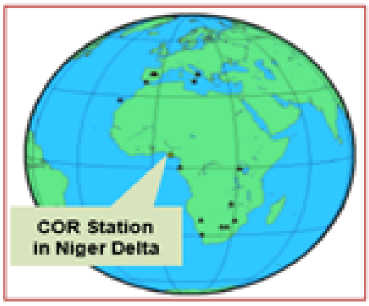

Figure 6: Station fixing using neighboring IGS Stations (AUSPOS Report)

Conversion of Raw data to RINEX- This conversion was done using Leica Geo office 4.2

- The RINEX file(s) contained more than one hour (preferably two) of GNSS data.
- The RINEX file(s) did not contain any data from the current Universal Time day [**Baltimore, MD,** (2016, August 2)].
- The antenna height is the vertical distance from the ground mark to the Antenna Reference Point (ARP).
- The IGS file naming conventions are met.

The nearest fifteen (15) IGS stations to AOI in Nigeria were used as the reference stations for the processing. That data is retrieved from Geoscience Australia's GNSS Data Archive.

3.0 RESULT

3.1 Achieved Accuracy

A precise fix for the stations were obtained using a 'double difference' technique computed with respect to neighboring COR stations. The coordinates of the IGS stations were constrained with uncertainties of 1mm for horizontal and 2mm for the vertical. During the process, effects of observation errors sources, such as receiver clocks, troposphere and ionosphere were considered, through modelling, and estimation of related parameters. All the computations were undertaken according to IERS conventions. All coordinates were computed in ITRF2008. The ITRF and WGS84 are generally considered to be equivalent (to within 0.1m).

Additionally, as part of the validation exercise, range test for both Radio RTK and GSM were carried out to confirm coverage. An accuracy of 0.02m was achieved within a 15km radius in RTK mode for radio transmission and 0.02m using GSM transmission mode at 30km away. Since the results of the validation exercise were found satisfactory, the final position was published and the station was thus commissioned.

3.2 Application in Oil and Gas Industry

The technology has found many applications within the oil and gas industry with demonstrable advantages over other survey techniques. Some of these include;

- **Well fix / Coordination survey**: The technology enables the accurate determination of Well positions within oil and gas fields. The position of gyro references can also be precisely determined for planning Well trajectories prior drilling.
- **Establishment of geodetic control pillars for seismic surveys:** In seismic prospects, both the source lines and the cross lines are uniquely designed and oriented such that spatial reference of positions become

Station	Longitude(East) (m)	Latitude(North) (m)	Ellipsoidal Height(Up) (m)
SGBB	0.004	0.003	0.006
HRAO	0.004	0.003	0.006
MAS1	0.004	0.003	0.005
MAT1	0.004	0.003	0.007
MFKG	0.004	0.003	0.006
NKLG	0.004	0.003	0.005
NOT1	0.004	0.003	0.006
SBOK	0.004	0.003	0.006
SFER	0.004	0.003	0.005
TDOU	0.004	0.003	0.006
VILL	0.004	0.003	0.006
WIND	0.004	0.003	0.005
YEBE	0.004	0.003	0.006
ZAMB	0.004	0.003	0.007

Table 1: Positional Uncertainty -95% Confidence level (AUSPOS report 2015)

easy. First order control extension across the prospect area is essential before densification with subsidiary controls. The CORS technology provides a reliable way to orient very large prospect areas economically and effortlessly saving time and cost.

- **UAV data gathering (PPK) and Ground Control Points (GCP) Establishment:** Post Processed Kinematic (PPK) combined with GNSS CORS enables data acquisition and processing over project area. Establishment of GCP for imagery orientation over vast areas can be done effortlessly with improved data harmony using the CORS system. This will usually yield well mosaic Ortho-photos and DTMs with little or no shift.
- **Subsidence monitoring:** GNSS CORS stations have capabilities to monitor minor ~~small~~ changes in position and elevation. These stations are currently being used for subsidence monitoring within the Niger Delta area [Harris Galveston, (2005)].
- **Land acquisition and Compensation Survey:** Acquired areas needs be properly surveyed to provide the right statistics for adequate compensation. Use of GNSS CORS provides highly accurate data for this purpose.
- **Oil Spill Mapping:** In the oil and gas industry, prompt emergency response is critical to business continuity. The technology is well suited for supporting oil spill mapping using GIS-compatible data collectors for highly accurate impact evaluation. This data is also useful for planning necessary impacted site remediation.
- **Facility As-Built survey:** GNSS CORS provide orientation for reliable as-built data capture in RTK or other appropriate modes as exemplified in many pipeline projects.
- **Encroachment surveys:** CORS provide quick and effective means of mapping and managing encroachment routinely.
- **Pipeline route surveys:** Where the project covers long kilometers of pipeline, orientations and alignment of pipeline can be managed seamlessly without running the risk of a mismatch. Its data has also been reliably used to calculate hydraulic analysis flow for new pipeline projects.
- **Map Update:** Existing legacy maps and base line information would be effectively updated using the technology for precise and detailed data capture.

Application areas outside the oil and gas industry include but not limited to: Highway / Engineering surveys for use by government agencies and contractors [**Baltimore, MD,** (2016, August 2)]. The execution of Cadastral survey for local government, state and regional mapping for land information management are viable areas of application.

3.3 Benefits

Example of CORS application to two (2) projects here described demonstrates significant benefits:

Geodetic Controls Establishment for a 3D seismic campaign in the Niger Delta.

Technical:

- Greater precision and improved reliability processing with more CORS stations.
- CORS eliminates reference station check, installation and attendant logistics.

HSE/Operational:

- Eliminated HSSE exposure for pillar search/ in-situ-check from 4 to 0 days.
- Reduction in exposed personnel from average of 8 to 5 personnel.
- Resource optimization to fewer days from: 12 days against 5 days

Cost savings

- No search and check for control pillars required, hence reduced cost.
- No Freedom to operate (FTO) -costs for using pillars outside the prospect area.
- Using less number of personnel and equipment to complete survey in lesser days.
- Achieved 60 - 75% cost reduction.

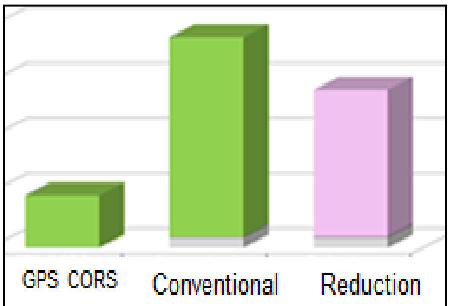

Figure 7: Cost Comparism

UAV data gathering (PPK) at Proposed Gas Project area

Technical / Operations

- Post Processed Kinematic (PPK) combined with CORS enabled acquisition and processing over forested and difficult area terrain with reduced number of GCPs.
- High quality Ortho-rectified imagery (2cm) and Digital terrain model (36cm) over the area of interest for pipeline route selection optimisation, facility design, and Land assessment (economic structures) prior to acquisition.

Derived benefits:

- Eliminated HSSE exposures associated with pillar search / in-situ-check from 4 to 0 days.
- Reduction in survey personnel numbers from average of 8 to 5 per crew outing.
- Resource optimization to fewer days from: 12 days against 5 days
- No search for ground control required, hence reduced cost.
- Less number of personnel and equipment, in less numbers of days.

4.0 CONCLUSIONS

GNSS CORS implementation depends mainly on infrastructural and technical frameworks which unfortunately are still at the developmental phase in Nigeria. These largely affects the cost and ease of implementation. One of such is the Broadband Internet access. The GNSS CORS requires dedicated access to internet. The options available are dependent on existing GSM service providers or setting up of standalone VSAT communication system. The GSM services are sometimes unreliable and the cost of setting up / maintenance of standalone VSAT system highly prohibitive. Nevertheless, there are continual improvements in the Nigerian internet market with the injection of 4G LTE internet service. This service is currently limited to the urban areas, and this has delayed the network solution activation. However, a stand-alone operational GNSS CORS stations is a good start point with reliable accuracies for those wishing to deploy CORS, with only reduced coverage to contend with.

Power supply is also a challenge in Nigeria and is a major factor considered in siting the GNSS CORS stations. So, the implementation was restricted to within oil and gas facility locations where power availability and reliability is guaranteed. This system offers a quick way of eradicating the use of local “origin” controls or project datums in remote areas as is currently practised. Besides integration requirement**,** there is currently limited in-country expertise. Consequently, institutions resort to single sourced “specialist” local vendor at significantly high cost, and acquisition of additional accessories by users to enable connectivity to the CORS system.

The implementation obviously is a game changer in Survey service delivery within the oil and gas industry, and should be extended to establishing Land Information Systems (LIS) in developing Countries including Nigeria as a cost effective, quick and accurate tool to update national utility and infrastructural maps.

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BIOGRAPHICAL NOTES

Mpaka O. Erekosima received his Bachelor of Technology degree (with honors) in Land Surveying / Geodesy from the University of Science and Technology Rivers State, Nigeria; Post Graduate Diploma in Satellite Image Processing from ITC, Enschede The Netherlands; and an Executive Masters in Business Administration degree (with distinction) from the Business School Netherlands (BSN).

He started his career in 1991 as a Surveyor with Seismograph services Limited, engaged in geophysical (Seismic) data acquisition. Later joined Shell Nigeria in 1994 as Projects Surveyor engaged in provision of positioning and surveying support services to pipelines, wells and facilities construction projects. He is currently the Head of Onshore Survey Operations in Shell Nigeria.

Benjamin Edewoh Onoriode holds an HND certificate in Land Surveying from Kwara State Polytechnic, a B. Tech. in Land Surveying from Rivers State University of Science & Technology (RSUST), Port Harcourt and a PGD certificate in ICT from Federal University of Technology, Owerri. He became a Registered Surveyor under Surveyors Registration Council of Nigeria (SURCON) in 2014 also a member of Nigerian Institution of Surveyors (NIS). Certified as HSE practitioner by NISP and a Drone Pilot by Nigeria Army Institute of Technology and Environmental studies (NAITES). He has over 19 years Onshore and Offshore working experiences, 14 years of which were spent working with different Oil and Gas servicing companies prior joining The Shell Petroleum Development Company of Nigeria (SPDC) where he currently works as a Geometrician