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A SEISMOGEODETIC DATA ACQUISITION NETWORK FOR EARTHQUAKE EARLY WARNING IN NIGERIA: A SEVEN-STATION PILOT

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ABSTRACT

Earthquake early warning (EEW) depends fundamentally on rapid detection by dense, reliable sensor networks capable of identifying ground motion and estimating magnitude before the arrival of destructive seismic waves. This paper describes a seven-station seismogeodetic network spanning Nigeria, which integrates high-rate GNSS receivers with broadband seismometers within a single, unified acquisition architecture. The stations transmit GNSS data automatically via cellular FTP and retrieve seismic streams through Güralp Discovery software, with all data archived centrally at the National Space Research and Development Agency (NASRDA) Center for Geodesy and Geodynamics (CGG), Toro. Solar power systems and local data buffering maintain station operation during frequent grid and network outages. After approximately three years of continuous operation, network data completeness exceeds 95%. The system does not yet issue alerts; the present work focuses exclusively on validating the data acquisition and transmission layer. To the authors' knowledge, this is the first unified seismogeodetic acquisition network in West Africa.

Keywords: Seismogeodesy, earthquake early warning, GNSS, broadband seismometry, Nigeria, network monitoring, remote station cellular telemetry, solar-powered seismic monitoring.

1. Introduction

Earthquake early warning (EEW) is fundamentally a competition between detection speed and wave propagation. P-waves arrive before S-waves and surface waves, providing a warning window of seconds to tens of seconds. To exploit that window, dense sensor networks capable of real-time communication are required (Allen & Melgar, 2019).

Traditional seismic networks rely heavily on strong-motion accelerometers and broadband seismometers, which record P-wave arrivals reliably. However, above approximately magnitude 7, these instruments clip and saturate, becoming unreliable precisely when accurate readings are most needed (Bock et al., 2011). Global Navigation Satellite System (GNSS) receivers do not suffer from clipping; they measure displacement directly across the full dynamic range of large-magnitude events. The trade-off is a lower sampling rate, noisier high-frequency data, and inability to detect the initial P-wave arrival (Melgar & Bock, 2013).

The integration of these two approaches, known as seismogeodesy, captures the advantages of both. Bock et al. (2011) showed how a multi-rate Kalman filter can fuse high-rate GNSS displacement with accelerometer records to produce broadband displacement waveforms that retain the low-frequency static offset and the high-frequency seismic detail. Crowell et al. (2012) extended this to finite-fault modeling for rapid hazard assessment. Since then, the approach has proven effective in the field, as demonstrated by the 2011 Mw 9.0 Tohoku-oki event (Melgar et al., 2013). Geng et al. (2013) applied the seismogeodetic approach to the 2012 Brawley swarm, highlighting its potential for earthquake early warning. The 2014 Napa earthquake (Melgar et al., 2015) and subsequent self-contained local EEW prototypes (Goldberg & Bock, 2017) refined the methodology for operational use. Saunders et al. (2016) further demonstrated the feasibility of low-cost MEMS accelerometers within seismogeodetic frameworks.

Africa, however, has been largely excluded from these advances. Seismic monitoring infrastructure across the continent remains sparse. Japan, California, and Chile maintain dense networks built over decades. Nigeria, located on the West African craton, has historically been considered seismically stable; that assumption is no longer tenable. The September 2024 Abuja tremor and recurrent seismicity around Mpape demonstrated the reality of intraplate seismic hazard in the region (Yekini et al., 2025; Olugboji et al., 2021). The Nigerian National Network of Seismographic Stations (NNNSS), operated by the Center for Geodesy and Geodynamics (CGG) under the National Space Research and Development Agency (NASRDA), currently comprises five operational broadband stations, with expansion ongoing (Eluyemi et al., 2024). The NGSA Seismic Network (FDSN code N1) incorporated Guralp 3ESPC seismographs following the 2018 Mpape M 3.2 event (FDSN, 2024).

However, to the best of the authors' knowledge, based on a review of NNNSS and CGG publications, no existing network in Nigeria—or West Africa—combines high-rate GNSS receivers with broadband seismometers within a unified acquisition architecture. This gap motivated the present work.

This paper focuses on network infrastructure rather than detection algorithms: architecture, deployment challenges, power-system design, cellular-connectivity constraints, and validation of system operability. We present the design, implementation details, and preliminary metrics from approximately three years of operation, including data completeness, transmission reliability, and the measures required to maintain seven remote stations from a single control center using Güralp Discovery.

2. System Architecture and Instrumentation

2.1 Remote Station Design

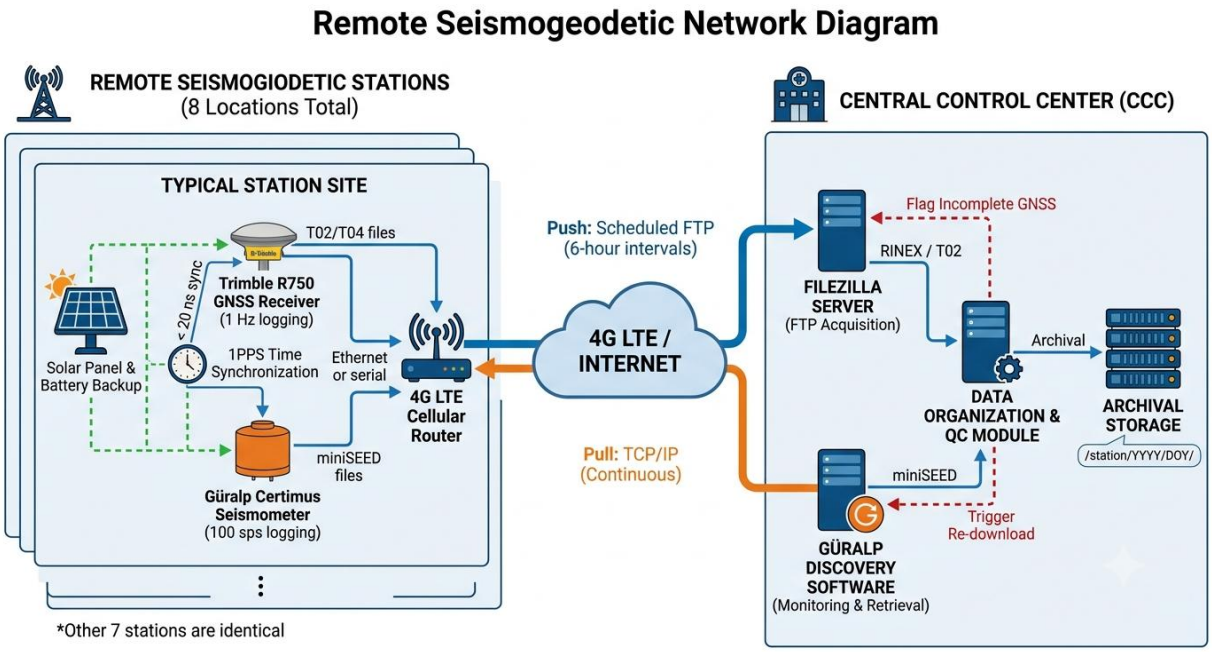
Each site is equipped with two instruments only, a design choice made deliberately to minimise complexity and points of failure.

The first instrument is a Trimble R750 Model 2 GNSS receiver, which tracks GPS, GLONASS, Galileo, BeiDou, QZSS, and NavIC through a 672-channel Maxwell 7 chipset (Trimble, 2023). It is configured for 1–10 Hz position output and raw logging in Trimble T02/T04 format, later converted to RINEX 3.x. The receiver includes integrated 4G LTE, Wi-Fi, Bluetooth, and Ethernet interfaces. Power consumption is approximately 6.6–8.5 W, depending on operational mode (Trimble, 2023).

The second instrument is a Güralp Certimus broadband triaxial seismometer. Its frequency response ranges from 120 s to 100 Hz, with a tilt range of ±90°. The unit incorporates a built-in 24-bit digitiser with >142 dB dynamic range, dual-redundant 16 GB microSD cards, and Ethernet and Wi-Fi interfaces. Its power consumption is <300 mW in ultra-low-power mode, enabling indefinite solar operation (Güralp Systems, 2020a).

Both instruments are housed in weatherproof enclosures. Solar panels and battery backup systems sustain operation during grid outages. Concrete pillars anchor the GNSS antennas, and the Certimus units are installed on levelled pads in shallow vaults. Standard geodetic practice was followed.

Figure 1: Data Acquisition Architecture and Workflow



Instrument selection and cost comparison. The Trimble R750 and Güralp Certimus were selected after evaluation of competing instruments at comparable price points. Table 2 summarises the alternatives considered and the principal selection criteria.

Table 1. Instrument selection criteria and approximate unit costs.

Parameter	Selected instrument	Alternative considered	Rationale for selection	Approximate unit cost (USD)*
GNSS receiver	Trimble R750 Model 2	Septentrio PolaRx5	Integrated LTE modem and native FTP client eliminate external communications hardware; 1PPS output enables direct digitiser synchronisation; lower power draw simplifies solar power design	8,000–12,000
Broadband seismometer	Güralp Certimus	Nanometrics Trillium Compact 120 s + Centaur digitiser	Built-in 24-bit digitiser and dual-redundant microSD storage eliminate the need for an external logger; <300 mW ultra-low-power mode extends battery autonomy; integrated Ethernet/Wi-Fi and Discovery compatibility enable remote firmware management	15,000–22,000

Note: Approximate costs based on 2023 manufacturer quotations; actual prices vary with configuration, warranty, and vendor terms.

2.2 Data Acquisition and Communication

The Trimble R750 logs raw observables—pseudorange and carrier phase—at 1 Hz. Its embedded FTP client pushes files to the central server every six hours. NTRIP was considered but rejected because it is designed for real-time kinematic correction streams rather than archival logging. FTP, by contrast, provides scheduled transfers, local buffering, retry logic, and no proprietary middleware. The R750 handles these functions natively.

The Certimus units are managed using Güralp Discovery (version 2.1). SeedLink, the IRIS standard, was also considered. However, SeedLink functions only as a data stream and does not support firmware updates, digitiser health checks, or remote reconfiguration without supplemental VPN or reverse-SSH infrastructure. Discovery consolidates these functions in a single platform. For a small team managing stations across Nigeria, this consolidation is essential.

The Certimus streams continuous data at 100 sps in miniSEED format, logging locally to dual redundant microSD cards. Discovery pulls the archived files over TCP/IP. Consequently, GNSS data are pushed, whereas seismic data are pulled. These represent two different architectures, reflecting the design philosophies of the two instrument manufacturers. The intermediate data logger was omitted entirely; no embedded computers (e.g., Raspberry Pi or industrial PCs) are deployed at the stations.

In the event of network failure, the R750 queues files and retries automatically. The Certimus continues writing to microSD. Each 16 GB card stores approximately four to six months of continuous three-channel data at 100 sps. Extended outages have occurred without data loss (see section 6.3).

Time synchronisation is provided by the R750's 1PPS output, fed to the Certimus digitiser. Accuracy is better than 20 ns (Trimble, 2023), which yields sub-microsecond alignment between GNSS and seismic streams. Sub-microsecond alignment is required for subsequent Kalman-filter fusion.

2.3 Communication Infrastructure

The seven stations span Nigeria: North-East (Yola, Toro), North-Central (Abuja, Mpape), South-West (Lagos), South-East (Awka), and South-South (Port Harcourt). All stations backhaul data via commercial 4G LTE. The Trimble R750's integrated LTE modem and the Certimus Ethernet interface connect to local cellular routers at each site.

At Toro, a FileZilla server instance receives the incoming GNSS files. A separate workstation runs Discovery for the seismic side. Each station has unique credentials. Files land in station-specific directories. TLS/SSL is enabled. Passive and active FTP modes are both supported.

2.4 Central Control Center

The control center consists of four subsystems:

1. **FileZilla server:** receives GNSS data, validates checksums, and logs transfer metadata.
2. **Güralp Discovery:** manages Certimus connections, downloads, and the health dashboard.
3. **Quality-control module:** parses incoming files and checks for temporal gaps, timestamps, and completeness.
4. **Archival storage:** structured directory trees (/station/YYYY/DOY/).

If a file is incomplete, the system initiates a retry. For GNSS, the R750 retransmits. For seismic data, Discovery re-queries the station's local storage.

Real-time fusion is not yet implemented. The Kalman filter, P-wave detection, and decision engine are under active development. This paper focuses on data-acquisition reliability and transmission integrity.

3. Remote Network Monitoring

3.1 Discovery in Practice

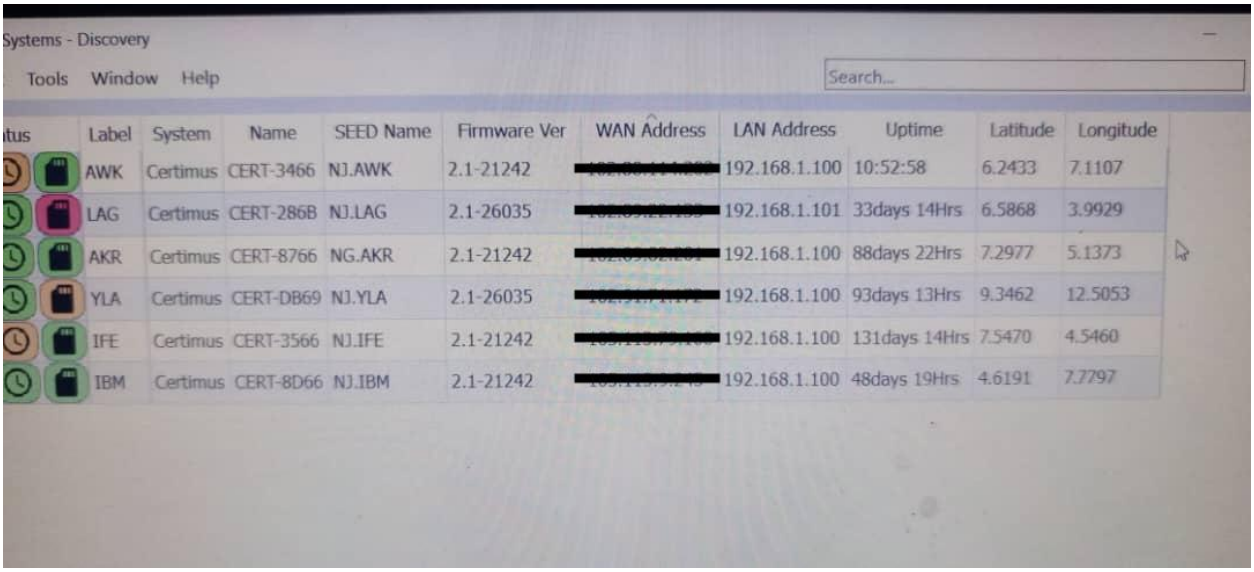
Discovery provides functions beyond data transfer, including comprehensive remote monitoring.

Network discovery: Discovery locates Certimus units on the network using their assigned WAN IP addresses. Each station sits behind a cellular router with NAT; Discovery tracks them regardless of dynamic addressing.

Firmware management: The authors currently run two firmware versions: 2.1-21242 (TOR, MPP, AWK, PHC) and 2.1-26035 (LAG, YLA, ABJ). Discovery pushes updates remotely. This eliminates the need for travel to remote sites for routine maintenance; for a team our size, that matters.

Health diagnostics. Discovery monitors internal temperature, digitiser status, GPS lock quality, storage capacity, and sensor orientation for each station. Anomalous states trigger warning flags that can be diagnosed and resolved remotely from Toro without interrupting data acquisition. Uptime tracking. Discovery reports continuous uptime since the last reboot. Toro achieved 145 days 8 hours, the longest recorded uptime in the current session, whereas Awka recorded 10 hours 52 minutes, indicating a recent power event. These metrics guide the allocation of limited maintenance resources. Automated downloads. Every six hours, Discovery pulls accumulated miniSEED data. Timestamps, file counts, and transfer durations are logged, providing complete visibility of data availability.

Figure 2. Güralp Discovery Network Status Interface



Discovery 2.1 shows the real-time status of operational stations. Green checkmarks indicate normal operation; warning flags enable remote diagnosis without interrupting data acquisition. Firmware versions, coordinates, and connectivity status are visible for each unit.

3.2 Why This Design Works

The decision to omit embedded computers was initially debated; however, the following considerations supported the minimalist approach. The rationale is as follows:

- Power. The R750, Certimus, and cellular router together draw roughly 12–14 W in total. Solar power remains easily sufficient.
- Failure points. This eliminates risks of operating-system corruption, external-logger SD-card failure, and remote security-patch management.
- Deployment speed. Each station can be deployed by two personnel in one day, a protocol that has been validated in the field.

4. Deployment and Network Configuration

4.1 Station Locations

Sites were selected to cover Nigeria's major geological provinces: the Benue Trough, Anambra Basin, Niger Delta, and the crystalline basement complexes of the south-west. Table 1 lists coordinates as registered in Discovery. SEED naming follows FDSN standards; network code NJ applies to all stations.

Figure 3. Seismogeodetic Network Map

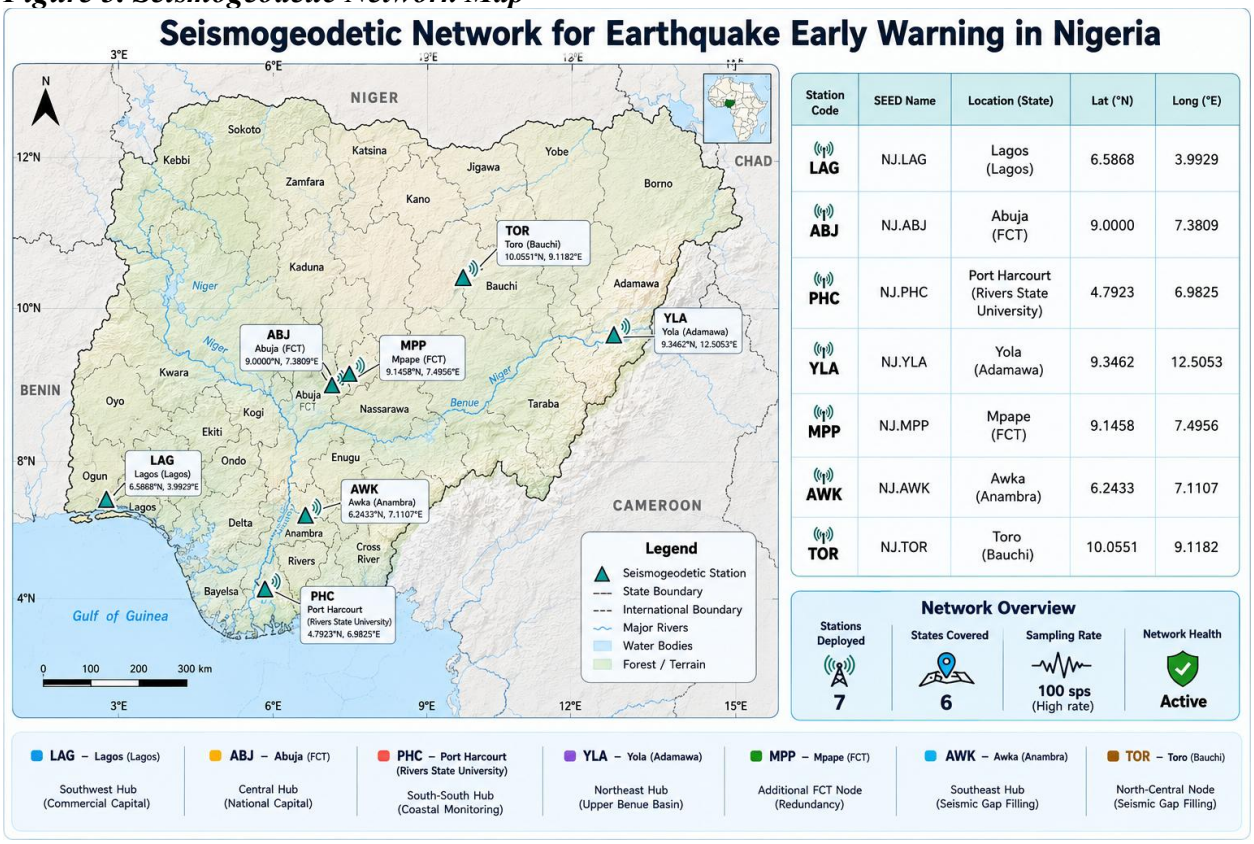


Figure 3 shows an approximate map placement, while Table 1 holds only verified, surveyed coordinates.

Table 2. Seismogeodetic station parameters.

Station Code	SEED Name	Location (State)	Lat (°N)	Long (°E)	Sampling Rate	Start Date	Discovery Uptime (current session)
LAG	NJ.LAG	Lagos (Lagos)	6.5868	3.9929	100 sps	2023	33 days, 14 hrs
ABJ	NJ.ABJ	Abuja (FCT)	9.0000	7.3809	100 sps	2023	25 days, 4 hrs
PHC	NJ.PHC	Port Harcourt (Rivers State University)	4.7923	6.9825	100 sps	2023	19 days, 4 hrs
YLA	NJ.YLA	Yola (Adamawa)	9.3462	12.5053	100 sps	2023	93 days, 13 hrs
MPP	NJ.MPP	Mpape (FCT)	9.1458	7.4956	100 sps	2023	67 days, 2 hrs
AWK	NJ.AWK	Awka (Anambra)	6.2433	7.1107	100 sps	2023	10:52:58
TOR	NJ.TOR	Toro (Bauchi)	10.0551	9.1182	100 sps	2023	145 days, 8 hrs

Note: Discovery uptime as of July 2026. Uptime reflects duration since last reboot or network reconnection.

The network spans approximately 5.3° in latitude (~4.8°N to ~10.1°N) and 8.5° in longitude (~4.0°E to ~12.5°E). This represents a large spatial extent for a seven-station array.

These seven stations constitute the seismogeodetic subset of the broader Nigerian National Network of Seismographic Stations (NNNSS), which currently includes thirteen broadband stations nationwide. The remaining six NNNSS stations (Ife, Akure, Akwa Ibom, Nsukka, Shaki, and Kaduna) operate as standalone seismic nodes without collocated high-rate GNSS receivers and are therefore outside the scope of this pilot.

4.2 Installation and Power Systems

4.2.1 Power

Remote seismometers and GNSS receivers are low-power electronics. They require reliable energy, and grid reliability in rural Nigeria is poor. Consequently, every station runs independently on solar.

Figure 4 illustrates the simulated circuit: 12 V, 200 Ah lead-acid battery for energy storage. Table 2 breaks down the actual electrical load based on manufacturer specifications for the instruments deployed.

Figure 4: Simulated Solar Energy Harvesting System with Buck DC-DC Converter

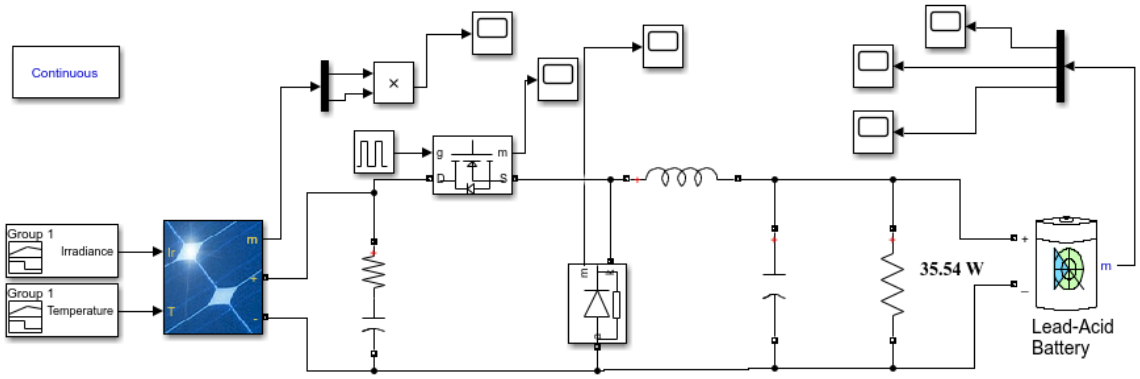


Diagram illustrates generic architecture; actual deployed load is ~12–14 W per Table 2.

Table 2. Electrical characteristics of a typical remote node.

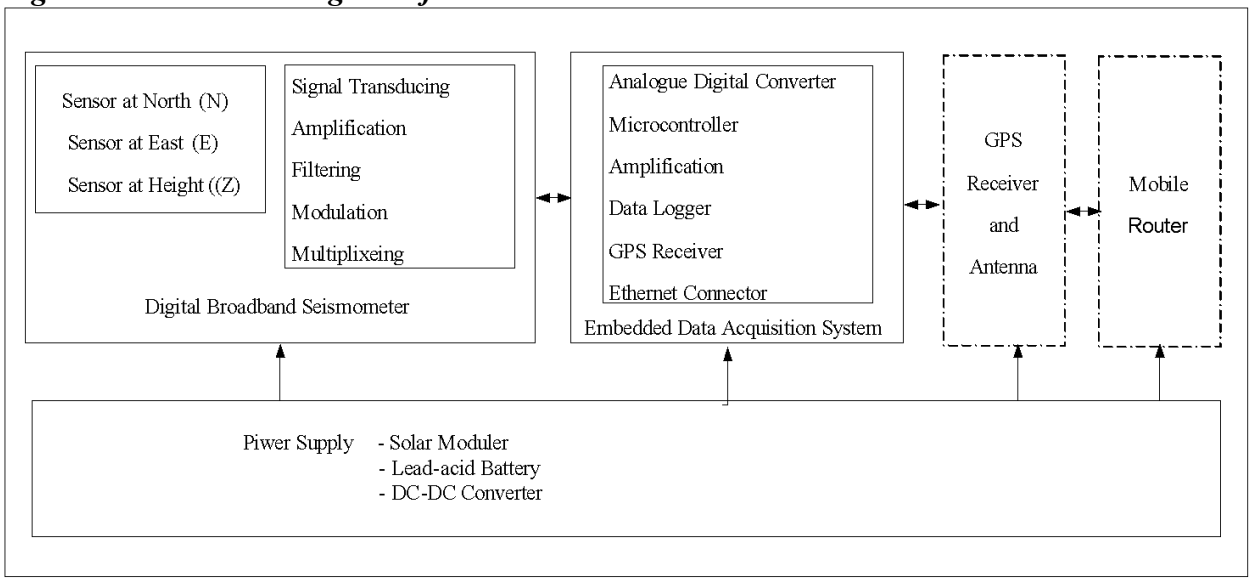
Subsystem	Nominal Voltage	Current	Power	Mode of Operation
Trimble R750 GNSS receiver & antenna	12 V	~0.55–0.71 A	6.6–8.5 W	Always
Güralp Certimus seismometer	12 V	<0.025 A	<0.3 W	Always (ultra-low-power)
Mobile router (4G LTE)	12 V	~0.46 A	~5.5 W	Always
Total (typical)	—	—	~12–14 W	—

The total draw of ~12–14 W is within the capacity of a 2 × 100 W solar array charging a 200 Ah battery. Even during cloudy spells, the station can run for several days on battery alone before reaching the 50% discharge threshold. Sites with chronic grid instability—notably Awka and Port Harcourt—were upgraded to larger battery banks after the first year.

4.2.2 Seismometer

A typical node includes the Certimus seismometer with its internal digitizer, the GNSS antenna and receiver, and the power subsystem (Duncan et al., 2020).

Figure 5: Schematic Diagram of the Instrumentation at Remote Seismic Node



4.2.3 GNSS Receiver and Antenna

A standardized protocol was followed at every site. The GNSS antenna is mounted on a fixed monument with clear sky view and connected via low-loss coaxial cable to the R750. The Certimus is installed on a concrete pad or in a shallow vault, levelled using internal MEMS sensors and verified in the field using GuVi Bluetooth (Güralp Systems, 2020b).

Solar panels—typically 2 × 100 W—charge the 200 Ah battery bank. The R750's internal battery provides UPS backup. The Certimus, at under 300 mW, can run for weeks on battery alone if the panels fail.

Uptime variation (Table 1) tracks local power stability and cellular quality. Some stations record months of continuous operation, whereas others show evidence of recent reboots following power events.

5. Data Flow and Validation

5.1 Volume and Throughput

The R750 at 1 Hz produces approximately 15–25 MB of RINEX per station per day. The Certimus at 100 sps, three channels, miniSEED format, generates approximately 50–80 MB per channel—approximately 150–240 MB per station daily. The total is roughly 200–300 MB per station, or ~1.4–2.1 GB across the network every day.

GNSS FTP transfers usually finish in 30 seconds to 5 minutes, depending on file size and network conditions. Discovery pull sessions run every six hours. A full-network download takes 10 minutes to an hour, depending on the volume of accumulated data and on LTE tower availability.

5.2 Validation Metrics

Table 3 summarizes network performance since 2023.

Table 3. Network validation metrics (2023–2026).

Metric	Value	Notes
Operational seismogeodetic stations	7	7 fully integrated in Discovery, (see Table 1)
Network operational duration	~3 years	First deployment 2023
Average Discovery uptime (current session)	54 days	
Longest continuous uptime	145 days 8 hrs	TOR
Shortest uptime (current session)	10:52:58	AWK (recent reboot)
Firmware versions deployed	2.1-21242, 2.1-26035	Remote updates via Discovery
Stations on 2.1-21242	4	TOR, MPP, AWK, PHC
Stations on 2.1-26035	3	LAG, YLA, ABJ
Network span (latitude)	5.3°	~4.8°N to ~10.1°N
Network span (longitude)	8.5°	~4.0°E to ~12.5°E
Daily GNSS volume (per station)	15–25 MB	RINEX 3.x at 1 Hz
Daily seismic volume (per station)	150–240 MB	miniSEED, 3 channels at 100 sps
Total daily network volume	~1.4–2.1 GB	7 stations
Estimated GNSS completeness	>95%	Expected vs. received files
Estimated seismic completeness	>95%	Discovery download logs
Time sync accuracy	<1 µs	GNSS 1PPS to Certimus digitizer
Power consumption (per station)	~12–14 W	Solar/battery sustainable

The >95% completeness was achieved only through robust local buffering and automated retry protocols. Nigeria's rainy season—May through October—degrades cellular signal strength, and extended outages are common. The R750 queues and retries automatically. The Certimus continues writing to microSD. When network connectivity resumes, all accumulated data are recovered, typically within 24 hours. FileZilla logs show the R750 recovering from transient

failures without manual intervention. Discovery's gap detection catches missing miniSEED files and re-queries the station automatically.

6. Discussion

6.1 Validation Results in Context

The >95% data completeness reported in Table 3 was achieved despite significant infrastructure constraints. Over the approximately three-year operational period, the network has maintained continuous acquisition through seasonal cellular degradation, grid instability, and extended tower outages. The variation in Discovery uptime—from 145 days at Toro to less than 11 hours at Awka—reflects heterogeneity in local power stability and cellular coverage rather than instrument failure. These metrics indicate that the architecture is sufficiently robust for operational deployment, provided that local buffering and automated retry protocols remain in place.

The daily data volume of approximately 1.4–2.1 GB is modest by modern seismological standards and is easily managed by the current FileZilla and Discovery infrastructure at Toro. However, the six-hour pull interval for seismic data and the corresponding FTP batch schedule for GNSS data introduce latencies of up to six hours for archival completeness. While acceptable for research and long-term monitoring, such latency is incompatible with true real-time earthquake early warning, which requires continuous streaming rather than store-and-forward retrieval.

6.2 International Network Comparison

The density and performance of the Nigerian pilot can be assessed against established seismogeodetic networks. In Japan, the GEONET GNSS array comprises approximately 1,300 stations across 377,000 km², yielding an average inter-station spacing of roughly 20–30 km (Geospatial Information Authority of Japan, 2025). In California, the ShakeAlert system integrates approximately 1,553 seismic stations and 1,100 geodetic stations across 423,000 km², achieving station spacing of 30–50 km in instrumented regions (U.S. Geological Survey, 2024). By contrast, the present Nigerian network spans approximately 920,000 km² with seven stations, producing inter-station distances exceeding 300 km.

This density gap has direct implications for capability. Japanese and Californian networks can detect and locate $M > 5$ events within seconds using P-wave arrival times and can constrain finite-fault geometry through near-field static displacement within minutes (Allen & Melgar, 2019). The Nigerian array, while capable of recording regional static displacement from large-magnitude events, cannot presently resolve small-event hypocentres or provide the spatial redundancy required for rapid, robust P-wave detection. Nevertheless, the >95% completeness achieved via store-and-forward telemetry with local buffering matches the data-retention reliability reported by dense networks, demonstrating that the fundamental acquisition layer is sound even under suboptimal infrastructure conditions.

6.3 Operational Constraints

Field deployment revealed practical constraints not documented in manufacturer datasheets. Fourth-generation LTE coverage is adequate in Lagos, Abuja, and Port Harcourt, but degraded in Yola, Mpape, and Awka, particularly during the rainy season. Dynamic Internet Protocol addressing from cellular providers necessitates adaptive firewall configurations; Discovery accommodates address changes, but the underlying network variability remains a design constraint.

Power grid instability at Awka and Port Harcourt required battery-bank upgrades and enhanced solar configurations after the first year. These modifications were operational necessities rather than theoretical contingencies, underscoring the importance of over-specifying power systems in regions with unreliable grid supply.

6.4 Lessons Learned

Three principal lessons emerged from the deployment.

First, standardization is essential. An early installation required two visits because of inadequate antenna grounding. Subsequent adherence to a revised, uniform protocol enabled consistent single-day deployment by two personnel.

Second, remote monitoring yields substantial cost savings. A single site visit costs approximately $500–$1,000 in travel and accommodation. Firmware updates and configuration modifications that previously required travel are now executed from Toro. Over the approximately three-year operational period, this capability has eliminated thousands of dollars in travel expenditure and weeks of personnel time.

Third, local storage is non-negotiable. In August 2024, Yola lost network connectivity for 72 hours. All samples were preserved on the Certimus microSD cards and retrieved without loss upon restoration. That incident validated the decision to implement dual-redundant local storage.

6.5 Toward Earthquake Early Warning in Nigeria

The September 2024 Abuja tremor, recorded by CGG/NASRDA stations, demonstrated that Nigeria's intraplate setting is not seismically inert (UNOOSA, 2025; Yekini et al., 2025). Yekini et al. (2025) identified pre-seismic strain localization in continuous GNSS data from a Trimble receiver in Mpape.

The present network extends that capability from a single instrument to seven collocated stations. Abuja (9.0000°N, 7.3809°E) and Mpape (9.1458°N, 7.4956°E) lie within the Federal Capital Territory monitoring zone. Once Kalman-filter fusion and P-wave detection modules are operational, the network will provide three functions: P-wave detection via broadband seismometers, unsaturated displacement estimation via GNSS, and rapid magnitude and location estimates for events captured within the array.

The current station spacing—hundreds of kilometres—is too wide for precise hypocentre location of small events (Goldberg & Bock, 2017). However, for large events where static displacement is measurable regionally, seismogeodesy can still deliver magnitude constraints and finite-fault geometry. The network represents a substantive first step toward operational earthquake early warning in West Africa.

7. Limitations

The following limitations of the current system are acknowledged.

The network depends on commercial 4G infrastructure. Local buffering covers temporary outages, but extended infrastructure failures—tower damage or provider maintenance—interrupt real-time availability. Satellite backup options (e.g., Starlink, Iridium) are under evaluation for critical stations.

Station density is insufficient for precise small-event location or array-based P-wave detection. The seven stations span approximately 920,000 km², yielding inter-station distances that exceed 300 km. By comparison, operational earthquake early warning networks in Japan and California maintain station spacing of approximately 20–50 km (Allen & Melgar, 2019). Because P-waves propagate at roughly 6–8 km/s in the upper crust, an earthquake occurring midway between two Nigerian stations must travel approximately 150 km before the first P-wave arrival is recorded, incurring a detection delay of roughly 20–25 s relative to a dense network with 20 km spacing. Robust hypocentral location requires three to four triggered stations; at 300 km spacing, this can introduce total detection delays of 30–60 s. For near-field events where the available S-

wave warning window is 10–30 s, these delays effectively consume the entire budget, leaving little or no time for protective action.

Real-time data fusion is not yet operational. The Kalman filter, detection algorithms, and decision engine remain under development. The network currently collects raw data only; automated alerting will be implemented in future work. Each site contains a single GNSS receiver and a single seismometer. If either instrument fails, a coverage gap results until replacement is possible. Future critical sites may receive redundant sensors. Poor cellular signal can stretch FTP transfers and Discovery downloads to 30–60 minutes. Such latency is incompatible with true real-time EEW requirements. The authors plan to optimize scheduling to prioritize near-real-time streams during seismic events.

8. Conclusions

This study has established a seven-station seismogeodetic acquisition network spanning approximately 920,000 km² across Nigeria. To the authors' knowledge, this is the first unified high-rate GNSS and broadband seismometer system of its kind in West Africa. Over approximately three years of continuous operation (2023–2026), the network has maintained data completeness exceeding 95% for both GNSS and seismic streams, with the longest continuous Discovery uptime reaching 145 days at Toro. The deliberately minimalist architecture—omitting intermediate embedded computers and leveraging native instrument telemetry—achieves a per-station power consumption of approximately 12–14 W, enabling indefinite solar-powered operation, and delivers sub-microsecond time synchronization between GNSS and seismic channels via the R750 1PPS output.

A single control center at NASRDA/CGG Toro manages the entire network remotely, including firmware updates, health diagnostics, and automated data retrieval. This architectural simplicity reduces failure points and operational overhead while supporting a daily data volume of approximately 1.4–2.1 GB.

Real-time seismogeodetic fusion, comprising the multi-rate Kalman filter, P-wave detection algorithms, and automated alerting engine, is under active development and is targeted for operational deployment by mid-2027. Concurrent network densification to 20–30 stations is planned to reduce inter-station spacing below 100 km, thereby enabling robust small-event location within the warning-time budget required for effective earthquake early warning in the region.

Data and Software Availability

Raw GNSS and seismic data are archived at the National Space Research and Development Agency (NASRDA) Center for Geodesy and Geodynamics, Toro, Nigeria. Data will be made available upon reasonable request to the corresponding author. Güralp Discovery v2.1 and FileZilla Server are commercial software used as described by the vendors.

Acknowledgments

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