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Enabling Multi-Disciplinary Geophysical Stations: Leveraging Real-Time Seismic Network Infrastructure

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Abstract

Providing high quality robust geophysical monitoring requires the highest level of performance and reliability from purpose-built instrumentation and its related infrastructure. There have traditionally been parallel efforts between complementary scientific disciplines, leading researchers to deploy their infrastructure independently. This sometimes results in redundant infrastructure such as telemetry and power subsystems, parallel schemes for data collection and even land use permits. This duplication increases costs that can limit station count, reduces the coverage of monitoring networks, and makes interdisciplinary collaboration more difficult. In recent years this inefficiency has been recognized and the need for combining scientific objectives to increase efficiency has been increasingly apparent. This is reflected in initiatives such as the merging of the SAGE (seismology) and GAGE (geodesy) programs, and the multidisciplinary approach of SZ4D.

Modern seismic data loggers, such as the Nanometrics Centaur, provide a number of key capabilities to enable them to act as the foundation for a multi-disciplinary station. This includes supporting inputs and metadata management for multiple types of geophysical sensors (both analog and digital), low power consumption, precise timing, and reliable data delivery with automatic back-fill features.

At its core, the Centaur is a high-performance datalogger originally tailored to seismic monitoring. Over the last several years it has also been increasingly deployed to facilitate the acquisition of geodetic, infrasonic, meteorological and magnetotelluric data. These additional sensor and data types are supported with purpose-built capabilities that allow multi-disciplinary stations to function with the same proven performance, reliability and effectiveness of a Centaur seismic station.

Both the existing and planned capabilities that enable the efficient support of multi-disciplinary geophysical sciences are discussed.

How we measure

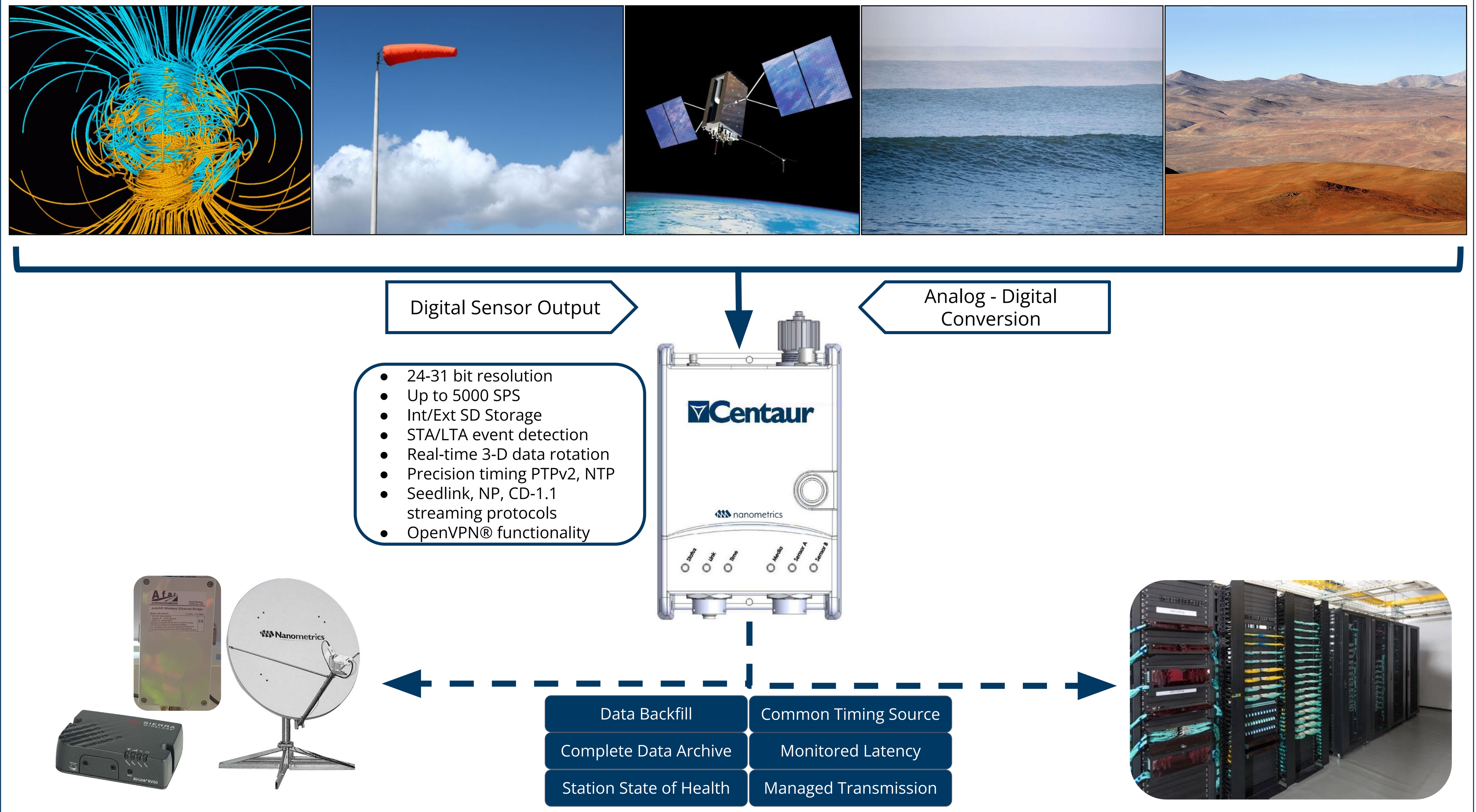
Conceptually, the data flow for geophysical measurements is straight forward. First, geophysical phenomena of interest are sensed by an instrument (e.g. seismometer, magnetometer, etc) that provides an analog or digital output. Analog data are then converted to a digital form to aid in its local recording and transmission. Data and associated metadata are stored locally and transmitted for central storage, analysis and/or archiving.

In practice, things are not so straightforward.
The means of sensing can vary significantly in complexity and cost. Digital formats are not consistent or compatible across disciplines (or even within disciplines). Even recording is not straightforward: just as the fidelity of the measurement itself is critical, so is the precise time it was taken - particularly if it is to be used with concurrently captured datasets. Transmission can be complicated, power-intensive or expensive especially in remote regions, and latency of data transmission may be critical in certain real-time use cases. Ultimately, the quality of the data analysis for geophysical studies relies on the effectiveness of each of the previous steps.
For remote geophysical stations, success depends on practical considerations affecting both performance AND reliability. Power is a primary concern - an unpowered station will not fulfill any of its functions. Transmission is equally challenging. Dropped packets and downed datalinks are common occurrences, and without robust mitigations these challenges will invariably lead to loss of data. Multiple data logging systems at a single station may compete for power and bandwidth, and may use very different data timing references.

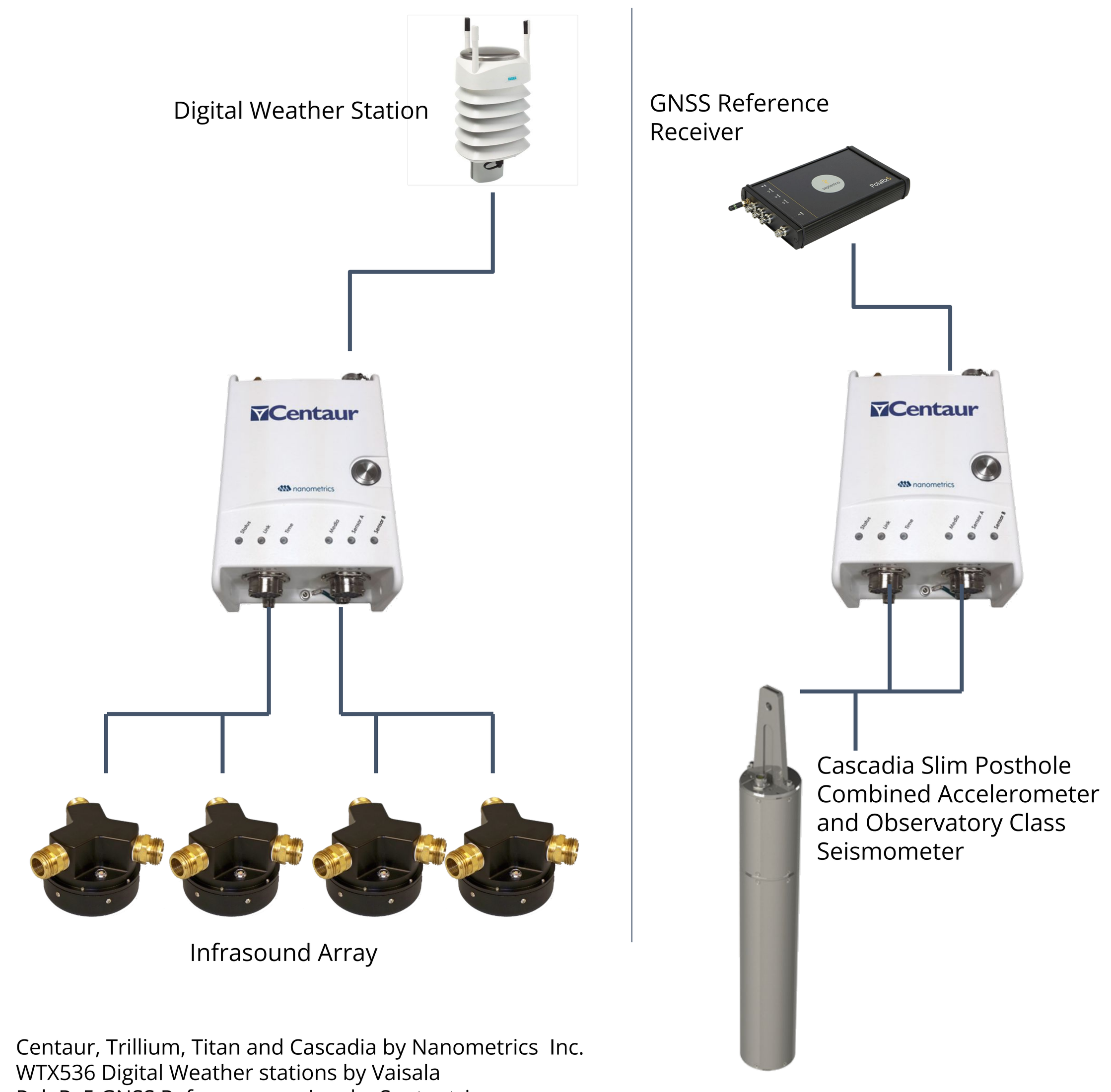
All is not lost ...
These practical considerations that challenge all geophysical measurement systems have become core design goals of modern geophysical data loggers such as the Nanometrics Centaur, and have been proven in seismic stations that operate reliably in some of the most inhospitable and remote locations in the world.

Station effectiveness, performance and reliability must address these key objectives:

A more comprehensive station



Listening to the Earth



Centaur, Trillium, Titan and Cascadia by Nanometrics Inc.
WTX536 Digital Weather stations by Vaisala
PolaRx5 GNSS Reference receiver by Septentrio
Model 64 Infrasound sensor by Chaparral Physics

Stations based on Nanometrics dataloggers have long supported geophysical sensing beyond seismic.
Specific capabilities make seismic dataloggers, like the Centaur, particularly well suited to this task:

- Consistent and reliable high fidelity acquisition at industry leading low-power
- Robust to the environment with IP68 and polar temperature ratings
- Best in class user experience giving confidence that your station is correctly configured the first time every time
- Broad support for analog and digital sensors
- Secondary sensor data with Station Network Channel Location (SCNL) allows existing archiving systems to 'just work'

Recent developments, including new interfaces added in our next generation Centaur have:

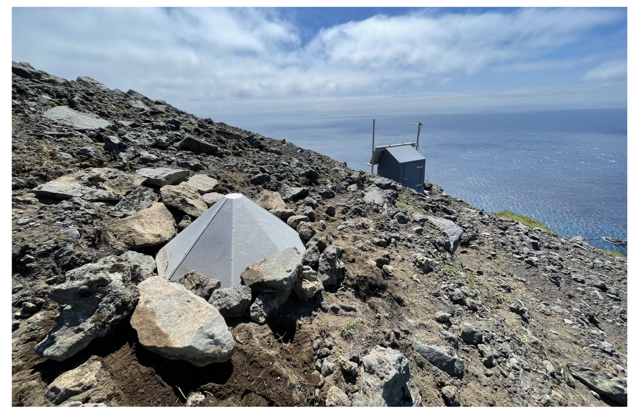
- Expanded the number of concurrent digital devices
- Expanded library of full sensor support
- Increased station integration options
- Maintained and improved low power leadership
- Support to add to the number of analog and digital channels, with very low power

Selected examples

Multi-disciplinary stations are not a new concept, but in many cases the support for these stations is not widely known, or limited to specific communities of interest.
While the equipment capabilities to support a wide range of sensor types has been expanding, the opportunities to apply this capability has also started to grow. Below are a few recent examples of geophysical stations using the Centaur that are not limited to seismic measurements to meet their science and monitoring goals.

A Multi-disciplinary station on Cleveland Volcano, AK (Carlisle Volcano in the background). The overall system includes multiple Centaur Networked Dataloggers (1), the system also includes Seismometer (Trillium Compact), GNSS Reference Receiver (2), and Triaxial Magnetometer measurements. The secondary hut (3), includes camera systems to monitor the plume.
Photo: Bacon, Conor
Image courtesy of the LDEO / Columbia

Shallow-braced GNSS monument using Centaur automatic backfill features with a Septentrio PolaRx5 GNSS Reference receiver. These features allow automatic recovery of data after service interruptions and tracking of complete acquisition metrics including latency monitoring.
Photos: Laporte, Michael
Image courtesy of Nanometrics



An Alaska Volcano Observatory Infrasound sensor under shielding (foreground) at site GASW, Gareloi Volcano, Andreanof Islands, western Aleutians. Acoustic and Seismo-Acoustic stations throughout the observatory take advantage of the low-power, robustness and reliability of Centaur.
Photo: Boyce, Ellie
Image courtesy of the AVO/UAF-GI.

A view to the future

Operating high performance, low-noise stations in the most remote locations has provided invaluable knowledge to continue to expand capabilities for multi-disciplinary science to enhance our ability to listen to the Earth. Beyond the complexity of the instrumentation itself, establishing reliable communications, power and data and metadata infrastructure also present challenges. Employing common data recording, transmission and management infrastructure to serve all or most geophysical monitoring needs at multi-disciplinary stations can significantly reduce capital and operating costs, as well as improve usability and promote interdisciplinary collaboration.

To this end, Nanometrics is continuing our evolution of geophysical monitoring products to

- Serve as a platform of choice for multidisciplinary geophysical monitoring stations
- Maintain our focus on performance and reliability to ensure outcome certainty
- Leverage the high precision common time base for more complete and correlated datasets supporting novel analyses
- Enhanced scaling options to keep station power and footprint low even as the number of concurrent measurements grow
- Provide direct support for an expanding range of geophysical measurements

Nanometrics is focused on providing trusted solutions to enable investigation and monitoring to globally grow our understanding of the Earth and its processes and impacts.