Monitoring Status and Data Retrieval for Pegasus Portable Seismic Stations

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Abstract

Remote monitoring of station operational health is an essential tool for portable scientific campaigns. Remote monitoring, when combined with Pegasus Digital Recorder and the Trillium Compact Horizon weak motion broadband seismometer, allows operations personnel to monitor the status of an Earth sciences data collection station at regular intervals to determine the station's health, ensuring a campaign's successful outcome. By leveraging satellite communications, Pegasus provides daily status updates, eliminating unnecessary check-up visits; alternately, it may expedite a visit if something happens at the station that needs addressing.
The compact, environmentally rugged combination requires less than 0.5 watts of total power to operate and supports very low-power communications systems for research that is well served by deploying portable stations with later retrieval of data.Historically, institutional seismic monitoring has used telemetry for real-time applications but at a relatively high-cost point for the institution, thus making it difficult for researchers without a large facility support and funding to consider. With power-cycled modems, a Pegasus Digital Recorder can provide state of health monitoring and even remote data retrieval with a very low size, weight and power footprint and at a very low cost.

Portable Instrumentation Ecosystem

Size, Weight, and Power (SWaP) are key considerations in selecting instrumentation to reduce the size of the power system and equipment logistics. With recent developments, Pegasus Digital Recorders can now be paired with low size, weight, and power (SWaP) communication technologies to enable remote telemetry with the primary use case of remote state-of-health monitoring (SoH). In addition, remote telemetry can enable other telemetry-based workflows, such as historical waveform data retrieval and low sample rate sampling.

The Portable instrumentation and accessories (see figure 1) provided as part of the ecosystem are designed specifically to support Portable and Polar campaigns where the combined power consumption for the instruments can be as low as 400 mW without sacrificing the data fidelity and completeness expected for a high-performance seismic datalogger. Also, the software components included in the ecosystem (see figure 2) fundamentally transforms how seismic campaigns are conducted and ensures a successful outcome with complete ready-to-use data sets.

- Pre-define station templates ahead of time for quick and efficient deployment in the field
- Plug-and-Play functionality with Nanometrics sensors enables automatic station configuration
- Rapid data collection takes less than 10 seconds to retrieve one month of data ready-to-use MiniSEED data and StationXML metadata

Figure 1: From left to right, Pegasus Digital Recorder, Smart Battery, Trillium Compact Horizon, Trillium Horizon, Quick Deploy Kit

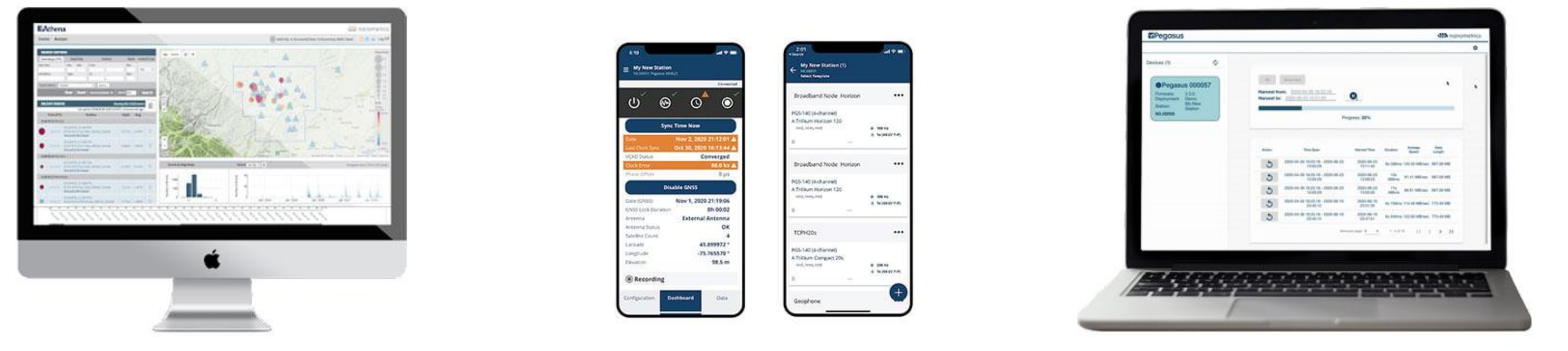

Figure 2: From left to right, Campaign Manager for central campaign management, Mobile Application for field management, and the Data Harvesting Application to create complete ready to use data archives.

Outcome Certainty with SoH Monitoring

Daily remote monitoring of a portable stations operational status enables quick and easy evaluation of a station's essential state of health (SoH) without requiring site visits and without the need to harvest detailed SoH information. Ensuring proper operation of remote stations while in service is essential to determine if maintenance is required in any of the four key areas (timing system, data acquisition, power systems, and sensing). Alternatively, based on regularly transmitted SoH information, a site visit can be deferred if everything is working well.

Nanometrics' turn-key state-of-health monitoring system includes a low-power consumption satellite modem that transmits state-of-health information daily to a user web portal, which then organizes and analyzes the information for possible fault conditions. When the user accesses the dashboard on the web portal, the summary status of a station will be displayed. It will show blue when no fault is detected and red when the station is in fault condition. When selecting a station in a fault condition, a simple error description is provided, as shown in Figure 3, where station XN.00332 is reporting an issue related to its GNSS timing system.

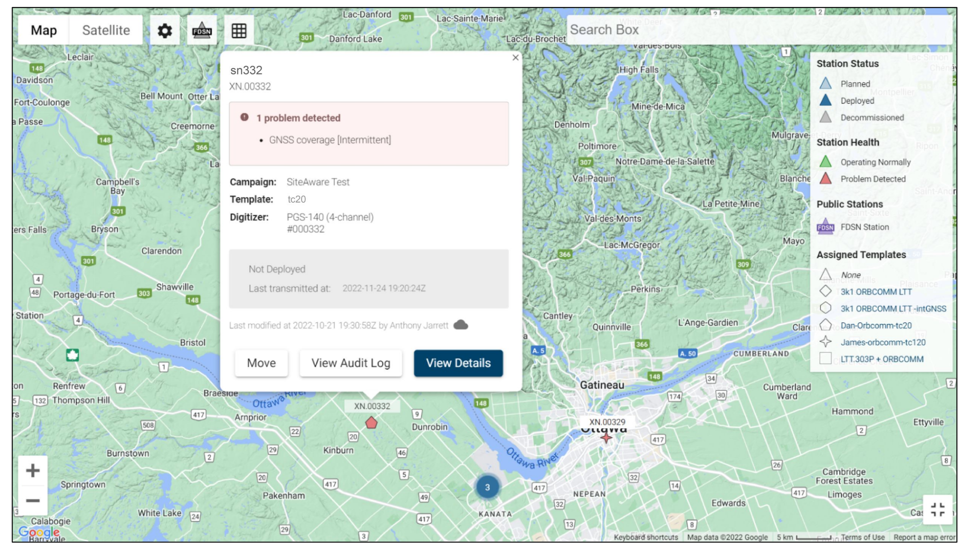

Figure 3: Screen capture from Nanometrics Campaign Manager showing the health status of a station indicating a GNSS problem

With the SoH information transmitted daily, it is possible to tabularize the values to review the historical state-of health performance, as shown in Figure 4. For example, a trend of continuous degradation in the battery voltage could indicate limited battery storage capacity or solar charging capacity. Reviewing this information before a site visit will allow a field technician to optimize the required spare parts list and logistics.

Configuration | Problems 1 | Health Timeline | Recent SOH

Show up to
5 most recent

Time	2022-11-24 18:40:01Z	2022-11-24 18:50:01Z	2022-11-24 19:00:01Z	2022-11-24 19:10:01Z	2022-11-24 19:20:01Z
Battery Voltage (V):	12.14	12.14	12.14	12.13	12.14
Main Current (mA):	67.55	67.28	66.44	70.25	78.44
System Temperature (°):	18.37	18.31	18.24	18.40	18.96
Sensor SOH 1 (mV):	3532.00	3528.00	3527.00	3525.00	3526.00
Sensor SOH 2 (mV):	3531.00	3527.00	3527.00	3526.00	3526.00
Sensor SOH 3 (mV):	3532.00	3528.00	3527.00	3526.00	3526.00
Sensor SOH 4 (mV):	939.00	938.00	938.00	938.00	938.00
Antenna Status :	Unknown	Unknown	Unknown	Unknown	Unknown
Satellite Count :	10	10	10	10	10
Time Uncertainty :	12 μs	21 μs	29 μs	37 μs	45 μs
GNSS latitude (°):	45.41	45.41	45.41	45.41	45.41
GNSS longitude (°):	-75.70	-75.70	-75.70	-75.70	-75.70
GNSS elevation (m):	83.00	83.00	83.00	83.00	83.00

Figure 4: Screen capture from Nanometrics Campaign Manager showing a table view of the daily state-of-health received over time.

To optimize the workflows for SoH monitoring, Nanometrics is leveraging edge computing by performing event monitoring on the Pegasus Digital recorder. This simplified view reduces the analysis effort and allows a user to focus on the known fault, which could be repositioning or replacing an antenna upon the next site visit.

To do this, Pegasus continuously monitors for fault events whenever a SoH parameter has crossed a threshold. Once this information is transmitted to a processing center, it is possible to plot a timeline view that displays periods of expected operation (in green) and fault conditions (in red). For example, in Figure 5, for the period shown, Pegasus did not observe any mass position faults, but the logic detected low GNSS satellite count occurrences.

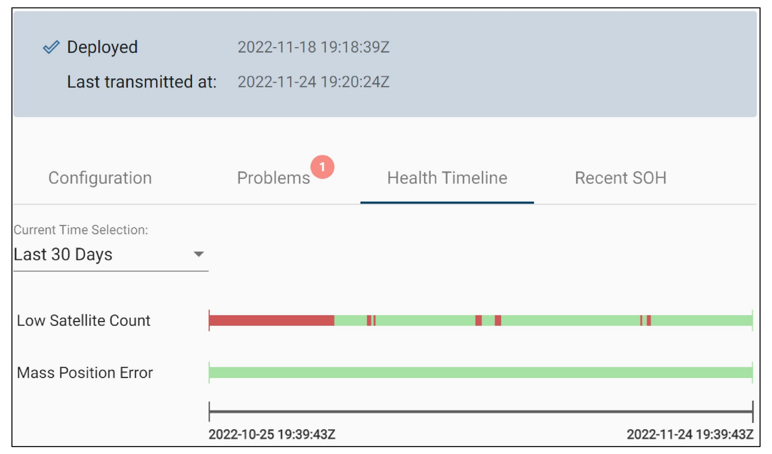

Figure 5: Screen capture from Nanometrics Campaign Manager showing a timeline of operation with fault indication.

Low Power Budget Impact

For SoH monitoring, the infrastructure can be optimized for the smallest, lowest power and lowest cost technology—a cellular modem if coverage is available or a short burst satellite modem for more remote installations. The remote monitoring infrastructure in the field, as shown in Figure 6, includes a wide area network (WAN) modem and an optional integrated or discrete controller for interfacing with the instrumentation. Together they share a power system that typically includes a photovoltaic cell, a battery and a charge controller.

When a modem is active, the station power consumption is dominated by the modem, which can be more than 10x that of the combined Pegasus and Trillium Compact instrumentation at no more than 460 mW. However, with remote monitoring, latency is not an issue which means the modem can be powered-off for extended durations and only enabled to transmit in bursts before returning to a sleep mode. A State-of-Health (SoH) summary message can be transmitted as a single small communications payload once per day and limited to a few seconds in duration, regardless of the chosen technology. When considering a daily instrumentation power budget of ~11 Wh, the incremental power consumption for this transmission is estimated to be < 0.1 Wh/day and therefore does not add much to the overall size of the power system.

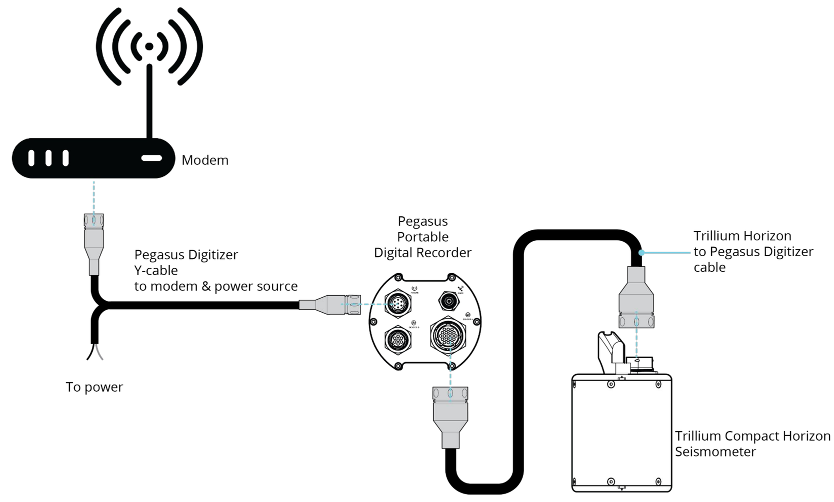

Figure 6: from left to right, Pegasus Digital Recorder, Trillium Compact Horizon, Pegasus OBS, and Trillium Compact OBS

Conclusion

Remote monitoring with Pegasus is ideal for portable scientific campaigns. Remote monitoring provides intra-deployment visibility of system performance to reduce the need for site visits and ensure a campaign's successful outcome. Additionally, with an instrumentation power budget increase of as little as 20 mW, remote monitoring can be done with minimal impact on the power system to reduce the overall system costs and related equipment logistics costs.

Forward-looking, in polar and ocean bottom environments where the cost of field visits is prohibitive or not possible, other use cases can be enabled. In these harsh environments, data telemetry can offer savings compared to the logistics cost of a site visit.

- **Low Sample Rate Sampling and Transmission:** reduce the power consumption and transmission costs to send a waveform data set by only sending low-sample rate data for analysis. High sample rate historical waveform data can subsequently be requested for the period corresponding to the event of interest using historical data retrieval.
- **Historical Waveform Data Retrieval:** Historical waveform data segments can be requested for a period of interest to supplement analysis. In more extreme use cases, such as polar stations deployed for 12+ months, the transmission costs over satellite communications can overcome the cost of logistics of field data harvesting and power management. Given its low power consumption, only SoH monitoring is enabled during the dark season. When abundant power is available in the solar season, a full waveform data set can be retrieved.

Figure 7: Portable Instrumentation ecosystem for ocean bottom, Pegasus OBS, and Trillium Compact OBS