

## CONNECTING INDUSTRY 4.0

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# SENSORS DEMONSTRATE A CRUCIAL ROLE IN MONITORING ACTIVE VOLCANOES

**NorComp** is a leader in the design, manufacturing, & marketing of interconnect solution products. Offering a wide range of premium, ruggedized, high reliability connectors for demanding applications in harsh environments.

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Humans have always wanted to be able to predict the future with volcanoes in their area. Such disasters on a fateful summer morning in 79 A.D. might have been preventable if they knew then what we know now. In the flourishing ancient city of Pompei, now near Naples in the Italian Campania region, the citizens were instantly buried with ash and debris from the volcanic power of Mount Vesuvius. This event was unannounced to the citizens of Pompei. The entire region was instantaneously frozen in time and converted to volcanic rock. The challenge to this date is to attempt to notify citizens of these possible occurrences and evacuate the area to avoid a repeat of this impending danger.

Now contemplate where humans stand approximately 2000 years after the Pompei disaster. Consider what our new sensors and equipment bring to the table to address this problem. The challenge before the Physical Volcanologist and scientists are determining which physical entities require monitoring and which sensors can capture pertinent information.

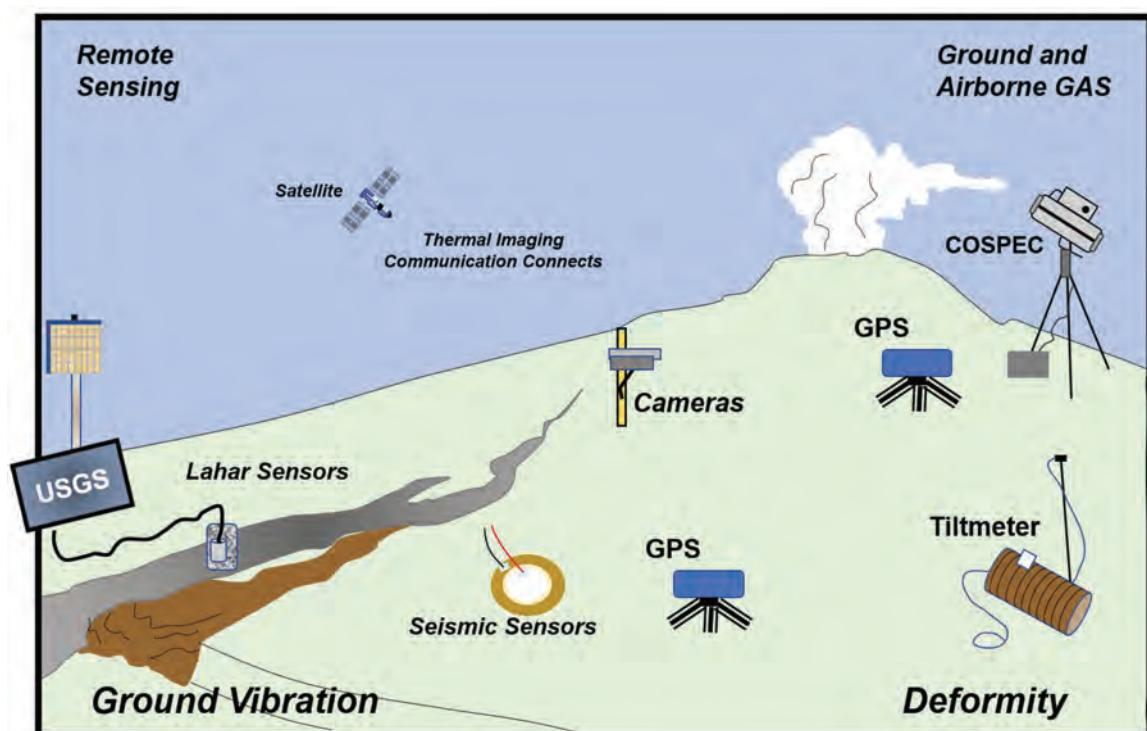
To address volcano predictions, data from physical occurrences such as earthquakes, the flow of debris, expelled gas, ground rotation, overall deformation of the ground, and human observations combine with data fusion techniques to provide the volcano engineer enough information to predict eruption dates 3 or 4 days before a volcano event.

To tackle these challenges, equipment with proper sensors and wiring connections ensures data transmission consistency. This article will show the assimilation of seismic, Lahr, tiltmeter, and correlation spectrometer (COSPEC) sensors. It then introduces NorCorp's waterproof circular VULCON™ STEEL, NANOOK™ D-sub, and QUIK-LOQ™ Push-Pull connectors.



# VOLCANO SENSING SYSTEM

Monitoring a suspicious area for a possible volcanic eruption requires multiple sensor tools with long-term survival in mind. These tools, combined with human observation posts, provide the Physical Volcanologist with appropriate information for volcano predictions. Over time, this information is combined using computer data fusion techniques to daily, hourly, or minute-by-minute map the data from different sensors to create the whole picture, hopefully providing enough information to notify adjacent population centers of dangerous conditions. A good arsenal of sensors/equipment includes seismic, Lahar, tiltmeter, gas, camera, and GPS sensors that utilize secure two wire RS-485 network protocols (**Figure 1**).



**Figure 1:** Volcano predictions require multiple different sensors to identify a complete picture of the current conditions. Data from these multiple differing sensors combine to create the complete volcano prediction picture.

The seismic sensors, typically used for earthquake events, measure and identify minuscule to significant earth movements. Lahar sensor determines and measures fragments that flow down a volcano's slopes, and tiltmeters detect minor land

rotation events. The correlation spectrometer (COSPEC) measures the volcanic gas content, and the system transmits data from all these sensors to a central location for further analysis.



## EARTHQUAKE MONITORS

The first earthquake or seismic sensor design was Chinese and dated to 132 A.D. The instrument resembled a six-foot diameter wine jar, with eight dragons positioned face down alongside the barrel. Each dragon marked the primary compass directions. Each dragon's mouth had a small bronze ball. Eight bronze toads sat underneath the dragons, with mouths waiting to receive a ball.

With an incoming seismic wave, the instrument sense would drop one of the balls, and the sound would alert observers, giving a rough indication of the earthquake's direction of origin. The device is said to have been very accurate and could detect earthquakes from afar.

These early sensors have progressed from those days to modern piezoelectric sensors. Today seismic sensors monitor earthquake events by measuring ground vibrations. Seismic sensors capture velocity or accelerometer events to sense the earth's vibrations, again from afar but provide magnitude and direction details. Cables with circular VULCON STEEL Upgraded M12 IP67/IP68 stainless steel connectors endure the pre-volcanic stressful conditions with EMI/RFI shielding and protection against dust (**Figure 2**).

The stainless-steel upgrade version is corrosion resistant and addresses vibration, shock, high pressure, and corrosive chemical environment, thereby reducing the need for cable replacement over time. These connectors easily connect to the system, that provides options of quickly adding additional seismic sensor channels or sensor replacement.

Additionally, using these sensors also encompasses security surveillance and resource exploration. Seismic sensors collect security intelligence on activities in a designated area. These sensors detect real-time ground vibrations and process the information to alert attendants of a security breach. Seismic sensors in these less stressful environments use waterproof NANOOK D-sub connectors. IP67 D-sub connectors ensure the reliable transfer of signal in stressful and harsh environments NANOOK D-sub connectors meet the demands for rigorous end-use applications. With sophisticated systems, seismic sensors can classify the source and location of the vibrations, such as people or vehicles. This level of seismic sensing is synergistic with volcano monitor requirements.



**Figure 2:**  
VULCON STEEL  
Upgraded M12  
IP67/IP68 stainless  
steel connector.

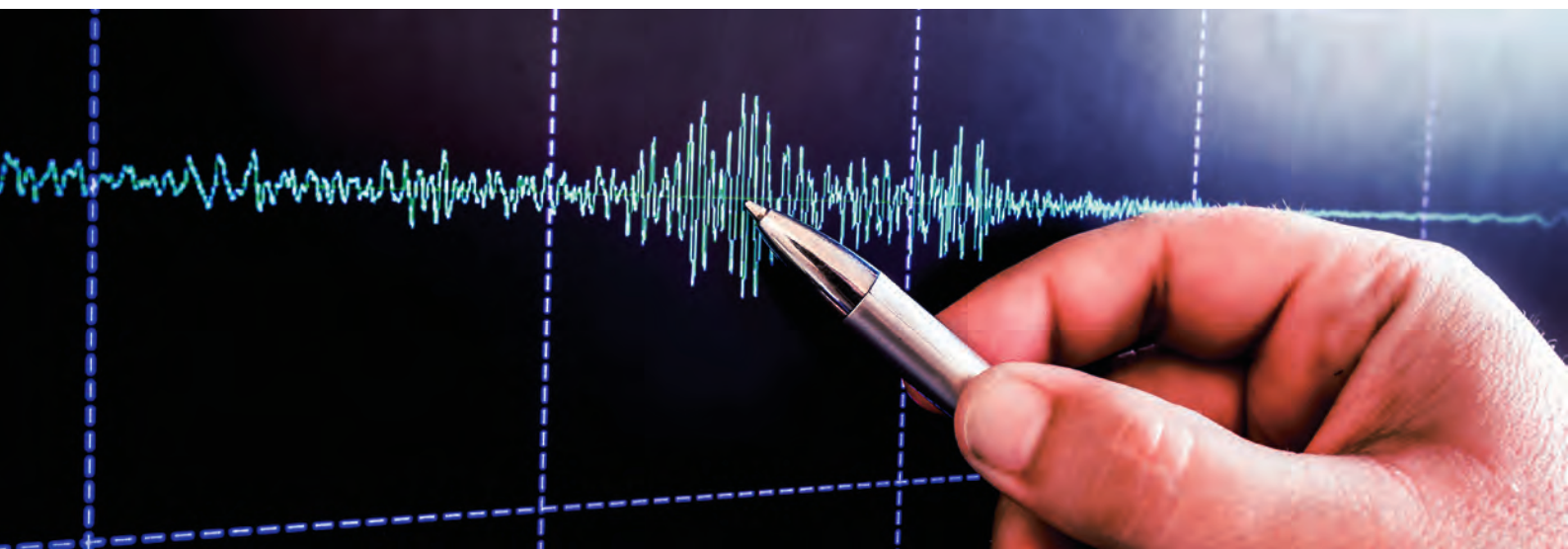




Figure 3: Waterproof NANOOK D-sub connector.

Typically, a volcanic seismic network is within 20 km (13 mi) of a volcano with 6 to 8 seismometers. This configuration can identify the volcano's magnitude and earthquake location. For very high-threat volcanos, having high-accuracy

measurements to track subtle changes in the earthquake location becomes critical. This instance can require that the Physical Volcanologist doubles the number of seismometer networks within 20 km (13 mi) of the volcano.

## LAHAR SENSORS

Lahar, an Indonesian term, describes a cold or hot mixture of water and rock fragments that flows down a volcano's slopes. These occurrences are mixtures of volcanic ash, water, rock fragments, tephra, and chunks of ice that flow like wet concrete and occur with little to no warning. Typically, Lahars arise with the rapid melting of snow and ice during eruptions, but it is possible that a sequence of these events as the volcano approaches eruption. Lahar events include liquefaction of large landslides or debris avalanches, breakout floods from crater lakes, and erosion of fresh volcanic ash deposits during heavy rains.

The Lahar sensors require a waterproof connector. NANOOK D-sub connectors

(Figure 3) meet the demands for rigorous end-use applications.

Lahar events typically occur in actual volcanic occurrences. Physical Volcanologists and scientists face the critical volcano challenge of detecting a potentially dangerous lahar as it is occurring so that public officials can issue warnings to people downstream. Additionally, United States Geological Survey (USGS) scientists use durable, portable, and easily installed systems to detect and continuously monitor the arrival and passage of debris flows and floods in river valleys draining active volcanoes.

## TILTMETER MEASUREMENTS



The tilt detection system's reliability and repeatability depend on the Physical Volcanologist's design type and preference. These design types include a simple pendulum, the bubble position under concave quartz (similar to a carpenter's level), or liquid-level systems (vaults or observatories).

One type of Tiltmeter is the differential capacitance transducer (DCT) which detects the position of hanging pendulums between two capacitor plates in a borehole tube. Linear voltage differential transformers (LVDTs) and DCTs determine

changes in height between the two ends of a liquid-level tiltmeter. This change can be in a 10-meter mercury-liquid level tiltmeters with 500-meter-long baseline tiltmeters.

The NorCorp QUIK-LOQ™ Push-Pull Connector is an appropriate connector choice for the Tiltmeter. This connector provides a fully shielded high-performance solution that is able to withstand shock and high vibration in harsh environments (**Figure 4**).



Figure 4: Push-pull connector

Under a concave quartz lens, a resistance bridge locates the position of a bubble in both shallow and deep borehole tiltmeters. This detection system was used in five of the seven tiltmeters installed in the San Francisco Bay area from 1992 to 2001.



## CORRELATION SPECTROMETER (COSPEC) SENSORS

Like many volcanoes, water vapor ( $H_2O$ ) is the most emitted gas, followed by carbon dioxide ( $CO_2$ ) and sulfur gases. The sulfur gases include hydrogen sulfide ( $H_2S$ ) and sulfur dioxide ( $SO_2$ ). The analysis and measurement of the magma water vapor help determine how much heat is present and at what depth.

The correct gas sensing location changes as the volcano comes closer to the ground. the QUIK-LOQ push-pull is a perfect connector as it is capable of withstanding shock and high vibration in harsh environments. The IP67/IP68 waterproof push-pull connectors are robust and reliable for this type of application.

Carbon dioxide ( $CO_2$ ) gas comes out of magma at deeper levels than other volcanic gases. Hydrogen sulfide and sulfur dioxide are the two most abundant sulfur-bearing gas types. An increase in  $CO_2$  may mean new magma is entering the system from lower levels. The amount of each kind in a gas sample reflects the volcanic activity state. A more significant amount of  $H_2S$  is usually a signal of quiet times. Groundwater filtering occurs as the sulfur gases rise from the magma through the groundwater. A greater  $SO_2$  level typically arises when magma is closer to the surface or when there is an increase in the amount of magma, both of which can indicate a potential eruptive activity.

## CONNECTORS FOR PREDICTIVE VOLCANIC ACTIVITIES

Connectors for volcanic monitoring applications must maintain a secure, reliable connection while operating in a harsh environment that includes extreme temperatures, shock, vibration, and the presence of liquids, ice, and mud.

Very active prevolcanic activity places multiple requirements on sensor boards and connectors, specifically when considering environmental conditions. Connectors are essential in maintaining reliability and repeatability in a rugged volcanic monitoring systems design.

There are several options for volcanic monitoring connectors, depending on whether data or power are needed at the system interface. In a volcano application, connectors with the seismic, Lahar, tiltmeter, and COSPEC sensors must endure stressful environments and protect against dust while remaining waterproof. The full metal shells and EMI/RFI shielding of NorComp's VULCOM circular, NANOOK D-sub, and QUIK-LOQ push-pull connectors provide reliable transmission mediums for differential signals. The standard differential signal, RS-485, is an inexpensive, highly reliable local network and multidrop digital communication link for industrial applications. This standard protocol allows thirty-two connected signals using differential signaling on two lines.

The internal volcanic monitoring sensors are printed circuit boards (PCB) with multiple connectors to provide data and power connections to the internal systems. Connectors may be board-mounted and connect to the PCB with a short cable. The connectors form an interface with the external environment, as the rugged volcanic monitoring connectors may be needed when environmental exposure poses a danger to system operation.

## CONCLUSION

The combination of multiple sensors and reliable wire connectors, such as VULCON STEEL, NANOOK D-sub, and QUIK-LOQ Push-Pull connectors from NorComp, create a high-precision, robust volcanic prediction system for the impending volcano.

To deliver the best overall performance, the NorComp connectors combine with seismic, Lahar, tiltmeter, and COSPEC sensors to create diverse volcanic prediction equipment. The VULCON STEEL, NANOOK D-sub, and QUIK-LOQ Push-Pull connectors offer full metal shells, EMI/RFI shielding and waterproofing capability to provide ideal connector solutions for volcanic sensing equipment.







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