QUANTUM™
TECHNOLOGY SCIENCES

RIGHT *of* WAY MONITORING *along* PIPELINES:

Thousands of Miles of Situational Awareness in a Single View.

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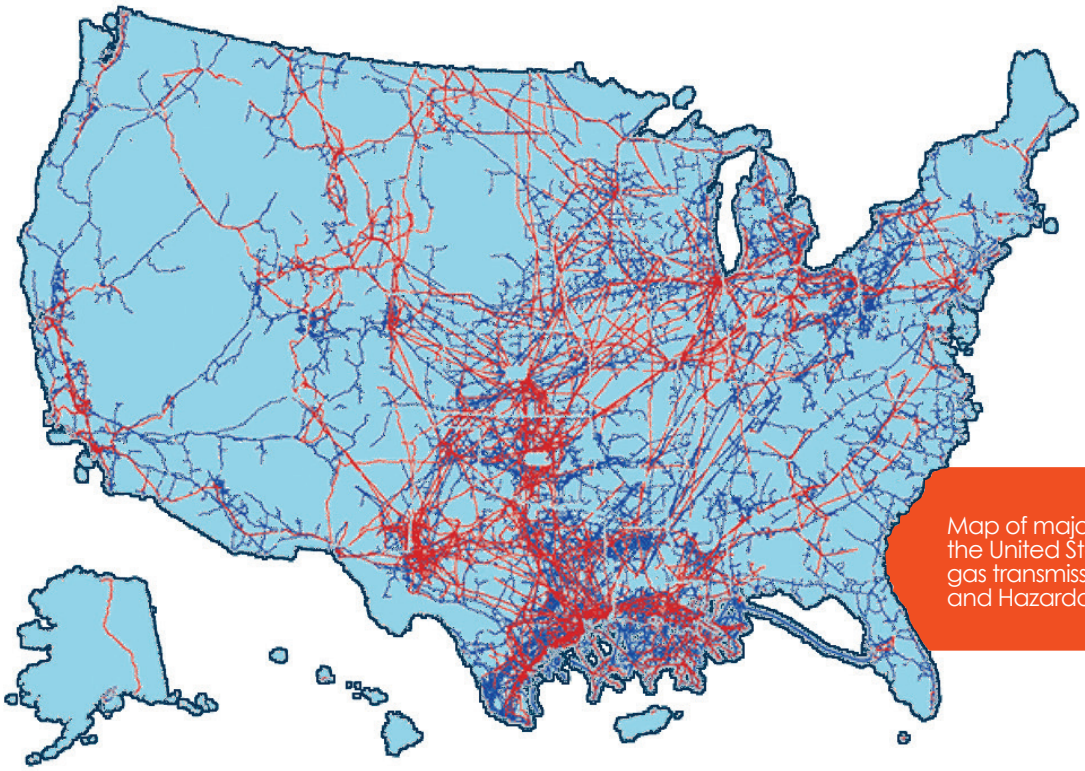


Map of major natural gas and oil pipelines in the United States. Hazardous liquid lines in red, gas transmission lines in blue. Source: Pipeline and Hazardous Materials Safety Administration.

MONITORING MIDSTREAM ASSETS & PERSONNEL ALONG THE RIGHT OF WAY

Visual inspection or responding to every alert along vast miles of pipeline can be expensive and ineffective. Threats are not always immediately present while the security force walks, drives, or flies nearby. Additionally, most video, fiber, RF, infrared, or geophone-based security offerings today lack one or more of the key ingredients of a successful pipeline security implementation:

- Reliable Classification - Delivering less than 5% False/Nuisance Alarm rates
- Detection and classification of threats at longer distances; fibre "walking" detection is typically accurate to only directly above and 10 meters to either side of the sensor
- Non-line-of-site detection – ability to overcome geographic and topographic barriers – RF and video devices are limited to what is visually in front of them
- Distinguish pattern of life activity from threat activity - most solutions cannot provide a learning mode to detect patterns or changes to patterns of traffic

Quantum's security solutions overcome these key barriers by providing a larger and more acute awareness zone with increased accuracy around assets. This provides security teams a more reliable indication of what is in the right of way and facilitates the optimal response based on the detection – be it trespassing, digging, or non-threatening pedestrian traffic.

CHALLENGES OF PIPELINE SECURITY

The United States has approximately 2.8 million miles of 2"-60" liquid petroleum, gas transmission and gas distribution pipeline. Most of it is buried but it still is susceptible to disruption or failure due to damage or fatiguing resulting from unauthorized trespassing, vandalism, theft or digging along the right of way.

Failure to protect the assets within the right of way has led to a loss of product resulting in decreased profits, increased costs in cleanup projects or fines, increased operational costs or delays, loss of public trust, or in the case of high-risk security areas, loss of life to personnel working along the right of way. Knowing what potential threats are approaching or traversing the right of way is crucial to today's security professional so that they may implement the appropriate deterrent or physical response to secure the property or personnel.

Pipelines carrying petroleum or natural gas often traverse remote environments where they are vulnerable to vandalism, sabotage, content theft, and other illegal and destructive acts. In some cases pipelines run through regions with known high risk, so crews/staff stationed or working along these rights of way are at risk of physical violence. Pipelines can be short in length, or may extend for hundreds or thousands of miles, both over-ground and underground. Threats approach by vehicle or on foot, and should they observe a security system, they will likely attempt to circumvent it or compromise it. Cameras can be blinded or destroyed. Above-ground sensors can be disconnected or disabled. Long, linear sensors such as fiber optics can be cut.

Quantum security systems are buried in the ground and are very difficult to detect. They are more sensitive than any other underground system, and are fully automatic, sending micro burst alerts in real-time when they detect and classify potential threats or threatening activities. They can also record alert log and state of health information to support subsequent "pattern of life" evaluations to help determine if the presence of threats or trespassers and their activities are predictable over time.

> "Quantum security solutions overcome key barriers, providing a larger & more acute awareness zone."

FEATURES OF QUANTUM TECHNOLOGY SCIENCE SOLUTIONS

Quantum offers a family of products which can be combined to deliver advanced awareness solutions for a broad range of physical security applications. This includes many elements of the oil and gas industry, to include midstream, the focus of this paper.

The assets associated with oil and gas are many and varied, and nearly all of them require increasingly effective security to counter growing physical threats worldwide. As in many other situations, 20th century technology and practices are becoming more inadequate for 21st century challenges. Modern physical security and surveillance applications require systems which:

- Create increased "awareness zones" to increase time and space for proactive security measures
- Are non-line-of-sight to alert on threats which cannot be seen because they are at great distance or are obscured by obstructions such as topography, vegetation, weather, or intervening structures
- Eliminate false alarms and minimize nuisance alarms while missing few, if any, alerts
- Can be scaled to monitor particularly long linear distances or large areas sometimes traversing states or countries
- Are concealable, with minimal vulnerability to discovery, evasion, or compromise
- Integrate seamlessly with legacy systems to improve overall effectiveness
- Are easy to install, need minimal maintenance, and are easily software-upgradable
- Integrate with deterrent systems to ward off unsophisticated attacks or deliver additional time for more forceful intervention
- Reduce manpower costs,
- Provide 24/7 coverage without being susceptible to coercion or bribery

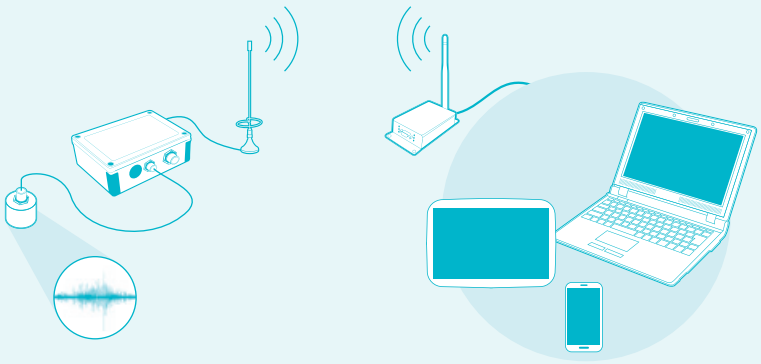
Quantum has designed its solutions to excel at all of these modern requirements. Its compact systems, based on award-winning, proprietary seismic-acoustic technology, will detect, classify, follow, and report potential threats to the user automatically and in real-time, all the time. Quantum's family of products is configurable to address multiple physical security requirements, to include

- Perimeters – providing awareness around permanent or mobile valued assets
- Linear features – providing awareness on either one or both sides of a long, linear asset, such as a pipeline or border.
- Temporary Security - portable, quick assembly solutions for protection of mobile assets/teams.

Whether remotely deployed in austere environments, or man portable for rapid response, the product family foundation, comprising a state of the art sensor integrated with advanced, intelligent algorithms, delivers value.

The oil and gas industry is a broad domain. The balance of this paper will focus on a specific midstream element – pipeline security and safety – but the approaches used are similar for other oil and gas applications.

> "Quantum offers a family of products which can be combined to deliver advanced awareness solutions for a broad range of physical security applications."



Quantum Systems convert vibrations in the earth into actionable information.

SYSTEM DEPLOYMENT & OPERATIONS

Quantum systems detect the presence of potential threats, determine the threat type, and alert the user to these facts. The systems do this by detecting and analyzing ground vibrations. Quantum systems are expert at detecting these vibrations, called signals, and exploiting the full fidelity of the information they contain.

Quantum's buried sensors detect acoustic vibrations and convert them into electrical signals which can be automatically analyzed to provide actionable threat information. The electrical signals are processed by a high efficiency computer node at the sensor, where they are automatically analyzed with advanced, state-of-the-art algorithms that can classify the energy source as a potential threat. The node alerts the user in real time to what has been detected, when, and where.

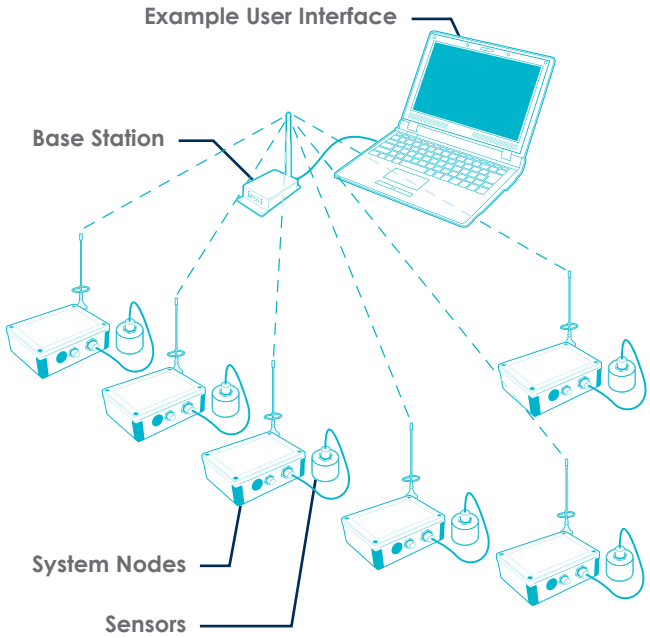
Configuring a Solution

Every pipeline solution is tailored to provide the most efficient and effective system for that application's needs. Building-blocks for a complete solution may have nodes configured with single or multiple sensors. This diagram shows a building-block style available for security and surveillance applications. Quantum solution designers work with the customer to determine the most cost-effective design to meet customer requirements.

System Installation

System installation is typically done by trained installers, particularly for a large, permanent deployment. The individual sensors are buried approximately 10" underground. The accompanying nodes may also be buried or may be mounted above ground, depending on the requirements of the deployment. Sensor location is important but not critical. In general, sensors are spaced for overlapping coverage of the faintest signals of interest.

The associated cabling for all types of deployments is shallow-buried if required. The only system elements that must be deployed on or above the ground are GPS, if necessary, and very small, low profile communications antennas if the solution is wireless. The remainder of the deployed system can be completely out of sight if desired. The standard wireless communications link is a line-of-sight RF HF Band radio. The communication range is determined by the transmission power and the antenna height. Other communications options are also available, including Ethernet 10/100, Ethernet radio, SatCom, over-the-horizon RF, cellular, and WiFi.



A view of the pipeline location and service road.

QUANTUM SYSTEMS AT WORK FOR OIL & GAS APPLICATIONS
ACTUAL PERFORMANCE RESULTS

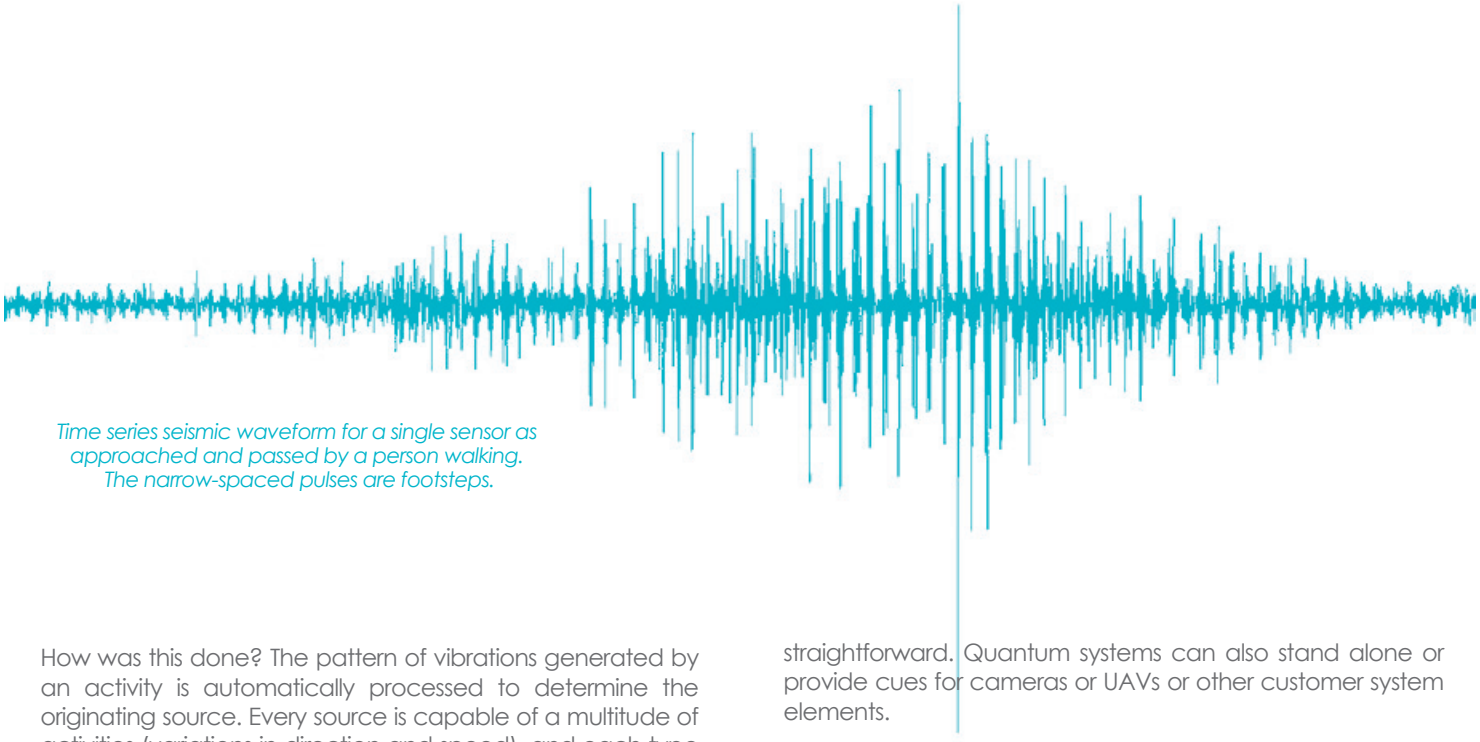
This Paper illustrates a typical midstream oil and gas security application by considering the monitoring of a natural gas pipeline for potential threats.

In less than an hour, Quantum staff deployed a four sensor system along more than 500 meters of natural gas pipeline in South Texas to automatically monitor for human footsteps and vehicles. The pipeline selected is located in a remote area of the state, and is easily accessible to threats seeking to damage it or compromise its performance. The area comprises scrub, with a cleared area approximately 40 meters wide along the pipeline. The pipeline is buried and has a parallel service road.

The infrastructure monitored was an operational 24-inch natural gas pipeline, part of a 91-mile section. The pipeline is steel, with a wall thickness of 3/8", and a design pressure of 1220 psig.

The data and results in this paper were generated by up to four deployed Quantum single-channel sensor systems communicating with a single laptop user interface. The systems were completely buried and concealed save for the small, whip RF communication antenna. In real time, each sensor system acquired technical data (seismic vibrations), processed the data, and reported, as programmed, micro-bursts of information regarding any analyzed signal produced by a source of interest.

> "Every pipeline solution is tailored to provide the most efficient and effective system for that application's needs."



Time series seismic waveform for a single sensor as approached and passed by a person walking. The narrow-spaced pulses are footsteps.

How was this done? The pattern of vibrations generated by an activity is automatically processed to determine the originating source. Every source is capable of a multitude of activities (variations in direction and speed), and each type of activity has its own unique vibrational attributes. This enables the computational analysis to accurately detect and classify the source.

Consider a person approaching a sensor. As the walker, a potential threat, comes within range of each sensor, the ground vibrations associated with his or her footsteps excite the sensors and are detected, producing a pattern, a pattern known as a time series seismogram. The narrowly-spaced pulses, resembling comb teeth in the time series, are the footsteps' energy, increasing in amplitude as the source approaches, then diminishing in amplitude as the source passes the sensor and moves away.

These types of signals are known as "impulsive transients". Within the sensor system, this energy is converted to an electrical signal which is further processed and analyzed by sophisticated software algorithms. In this case, the algorithms classify the sensed energy as footsteps, a potential threat. The detected signal is automatically processed and analyzed at the sensor site. Once classified with sufficient confidence, an alert is sent to a user interface or to a security Operations Center (SOC) or elsewhere for integration into a larger or legacy system.

The minimal bytes of information associated with an alert can be acquired and graphically displayed on any user interface. For this activity, the interface was a laptop computer. The simplicity of alert information makes integration of Quantum systems into existing security and surveillance systems to enhance their performance is very straightforward. Quantum systems can also stand alone or provide cues for cameras or UAVs or other customer system elements.

Two sensor deployments were used to create different threat situations for evaluation. In the sections that follow, four scenarios are described and analyzed

- people walking along a pipeline,
- people walking toward a pipeline,
- a vehicle moving along a pipeline, and
- a vehicle moving toward a pipeline.

The time and location "ground truth" for the simulated threats were determined using GPS. The ground truth information is co-presented on some of the following figures to illustrate system performance. A User Interface view is also provided for each scenario to illustrate what the user may see during the situations presented.

During all scenarios, each of the four sensors detected and classified all footstep and vehicle sources every time, for a probability of detection value of 100%.

> "Probability of detection value of 100%"

SCENARIO *one* 1 Walking Along A Pipeline

Simulated threat walking on service road above pipeline buried to left of walker concealed outside of the right of way.

In the first scenario, a single person walks and follows an underground, natural gas pipeline. As shown above, the person is walking along the service road, and the pipeline is buried parallel to this road in the cleared area, approximately 10 meters to the left of the walker's position.

The sensors are buried on alternate sides of the pipeline ajust outside of the right of way. To visualize scale, a 50-meter radius ring encircles each sensor. Sensor spacing is a function of many variables to include geometry of the asset, natural and unnatural background noise, geology, detection range to the origin point, nuisance alarm tolerance, and cost. These variables result in an overall probability of classification and defined "awareness zone." For example, the sensors could have been deployed closer together, resulting in more overlapping awareness zones for redundant areal coverage. However, in this scenario, a threat has no idea of sensor existence or placement, having minimal overlap or small gaps between awareness zones reduces the number of sensors required while still satisfying an acceptable probability of classification threshold.

The simulated walking threat follows a path along the pipeline and each sensor alerts to footsteps accordingly. For this particular scenario, the system performance resulted in an average 72 meter detection radius for footsteps. When a sensor detects potential footsteps, the system automatically analyzes the detected vibrations in detail to develop a statistical confidence that footsteps have been detected. When sufficiently confident, the system issues a footstep alert which continues until confidence in the classification drops below a threshold.

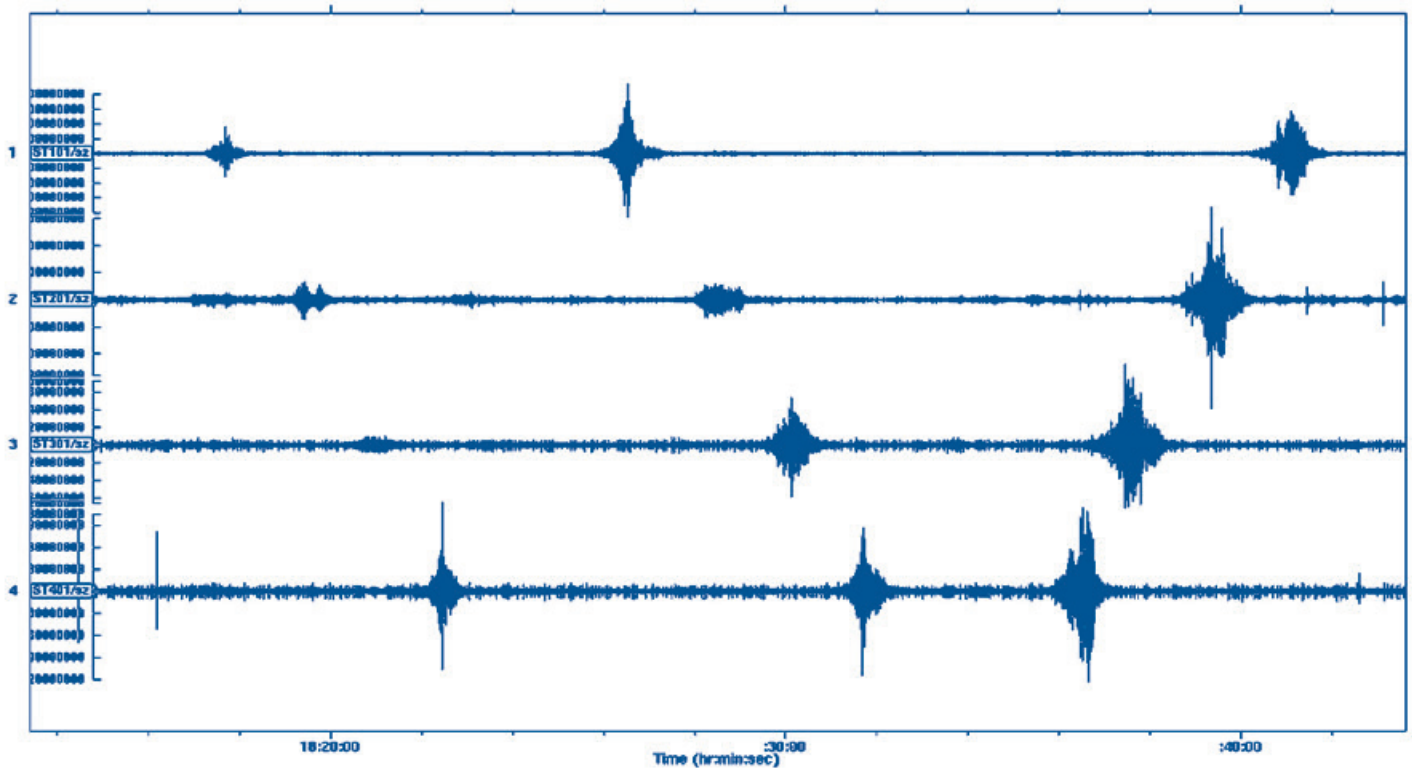
Two of the more important variables that influence detection radius are Probability of Detection (POD), the likelihood of correctly detecting and classifying the source, and Probability of False and Nuisance Alarms (P_{NA}), which is the incorrect classification of something that is not a potential threat as being a potential threat. These two variables trade off with each other. While increasing POD can increase range to the source, it can also increase nuisance alarms.

The user interface in map view shows the sensor locations, whether each sensor is functioning normally, and which sensors are alerting. The icons are at the sensor locations. A check mark on green indicates a healthy, functioning sensor, and a blue icon, this one of a walker, indicates an alert. At this point in the exercise, sensor #3 is alerting to the simulated threat, while the other sensors are actively monitoring. As the simulated threat continues to move along the pipeline, subsequent sensors will alert in turn, indicating the general threat location, its direction of movement, and an indication of its speed. Should the threat enter a motor vehicle and drive along the pipeline at some point, the walker icon would become a vehicle icon, indicating a moving motor vehicle. Other algorithms are available for classifying and alerting to other source activities as well, to include digging and objects in the air or water.

Sensor placement along pipeline. Sensors are placed on either side of the pipeline for better coverage. The 50 meter radius white circles are for distance visualization only.

Ground truth for a walker along the pipeline. The path followed is in red, and the alerts locations are in bright blue.

Screen shot of the user interface. At this point, sensor #3 is alerting. Sensors #1 and #2 have already alerted, and sensor #4 will alert as the walker continues NE along the pipeline.



Time series seismograms recorded by 4 sensors located just outside the pipeline right of way. Time moves from left to right. The observed signals were produced by various configurations of pedestrian movement along the pipeline.

Four walkers proceeding in an echelon formation southwesterly along the pipeline. Sensors are located in the brush outside the cleared area.

MULTIPLE VERSUS SINGLE WALKERS ALONG A PIPELINE

When multiple people walk in the awareness zone of a Quantum sensor, they generate greater combined signal strength and are easier to detect at greater distances. This is true whether they are walking in a small group or if they are separated into an echelon or other pattern.

The time series figure shows data recorded by the four sensors placed along just outside the right of way. It shows a single pedestrian, clustered group of pedestrians, and pedestrians in a diagonal echelon formation. Note that the signal strength and signal to noise ratio of the group of walkers is significantly greater than that of the single walker, whether they walk together or are spread out laterally over about 25 meters

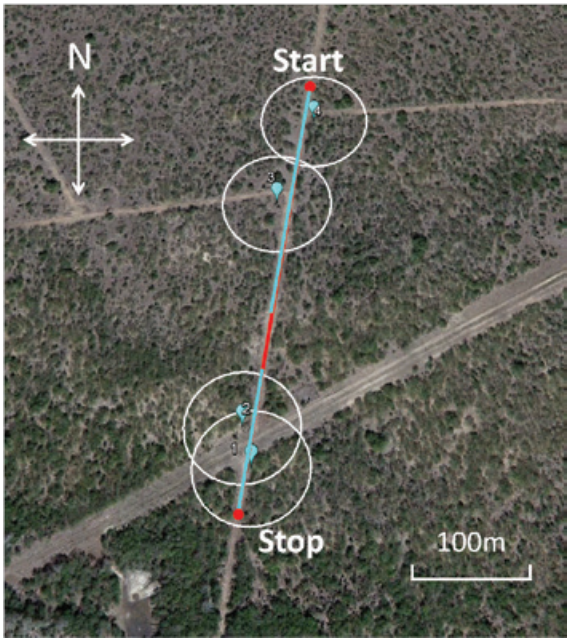
SCENARIO *two* 2 Walking Toward A Pipeline

A similar situation occurs if the potential threat is perpendicularly approaching a pipeline. The first sensor to have its awareness zone penetrated will send the initial alert to the user interface. Alternatively, additional sensors may be deployed away from the pipeline or along likely approaches to the pipeline location to provide additional time and space for a proactive security response. Four sensors were deployed along a road which accessed the pipeline and its adjacent service road. In this scenario, a single walker approaches from the north and proceeds south-southwest toward the pipeline location. Ground truth illustrates that the threat signal was detected immediately and classified by northernmost sensor #4, then sequentially by the sensors to the south.

User interface view, showing footsteps detection & classification by sensor #3

As in Scenario 1, the user interface map view indicates which sensors are reporting the presence of footsteps. Other user interface views are available as well.

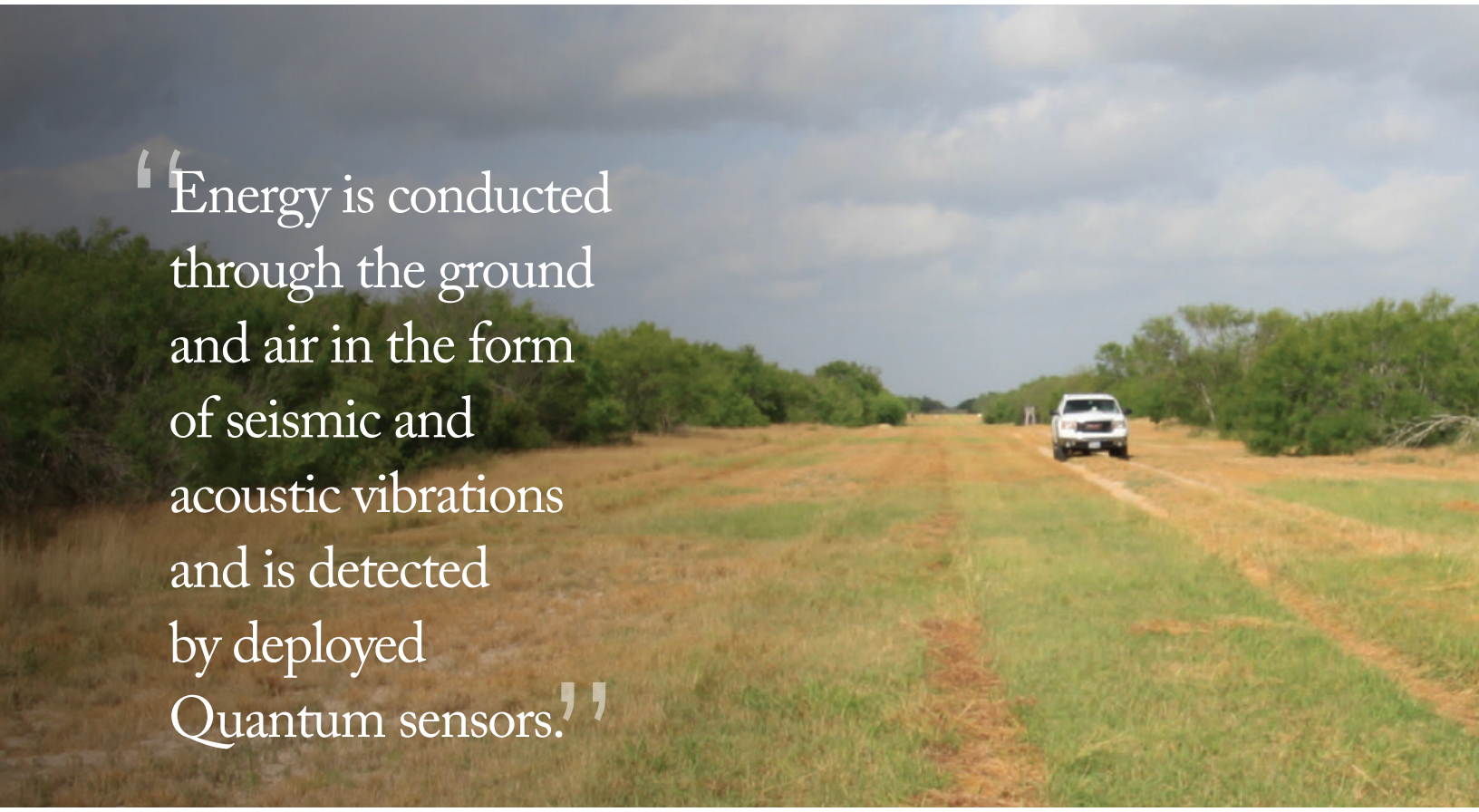
These include a historical log of previous alerts and other messaging with the individual sensors, and several control views for configuring the sensors and system for optimal performance. The "map view" in is generated automatically, and displays the sensor locations. If a sensor is relocated for any reason, the sensor location on the map view is updated to its new location.



Ground truth for a walker approaching the pipeline location via an access road. The path of the walker is shown in red, and is highlighted in bright blue whenever the sensor system is alerting on his presence

> "When a sensor detects potential footsteps, the system analyzes the detected vibrations in detail to develop a statistical confidence that footsteps have been detected."

SCENARIO *three* Vehicle Moving Along A Pipeline



The vibration pattern for a moving vehicle is known as an "emergent signal". As a vehicle puts more energy into the earth than a single walker, the detection range for a moving vehicle is significantly greater.

As a vehicle moves along the ground, it injects energy into the earth – engine noise, exhaust noise, and the road noise of its suspension system and tires making contact with the ground. This energy is conducted through the ground and air in the form of seismic and acoustic vibrations and is detected by the deployed Quantum sensors. The sensor layout for the vehicle scenario along the pipeline was the same as for the walker along the pipeline. However, the vehicle, being a larger source of energy, has a detection radius and subsequent awareness zone in excess of 150 meters.

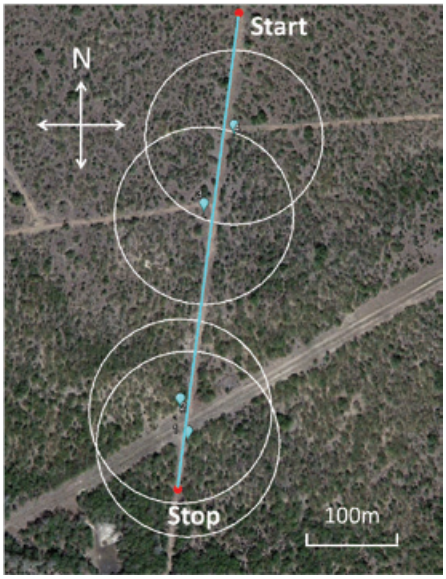
The vehicle, a 2008 Chevrolet Model 2500 pickup truck, moved from the southwest to the northeast along the access road maintaining various speeds for each run, between 5 and 15 mph. The truck was detected at all speeds and each time was classified as a vehicle. Quantum sensor systems have been demonstrated to detect and accurately classify vehicles at up to highway speeds.

User interface view of vehicle classification. As the truck continues along the service road, the subsequent sensors will display alerts with vehicle icons.

SCENARIO *four* 4 Vehicle Moving Toward A Pipeline

The fourth scenario is the case in which a vehicle was approaching the pipeline. The sensor layout is the same as was used for the approaching walker. Circles with 100-meter radius are drawn around the sensor locations for reference.

The detection range is so great that each pair of sensors have heavily overlapping awareness zones, resulting in simultaneous alerts. Had the potential threats stopped the truck and elected to walk the rest of the additional footstep alerts from the nearest sensor and southern sensors would have been issued. Had they approached the pipeline location and started digging down to the pipe, the digging alert would have been sent to the user interface and a "digging" icon (a shovel) displayed at the classifying sensor location.



Ground truth for a pickup truck approaching the pipeline location down an access road. The bright blue highlighted track is the truck location while alerts were reported.

User interface view for a vehicle approaching the pipeline location via an access road

> "Increasing the ability to deter attacks by responding with the appropriate level of action in a timely fashion."

CONCLUSION

The results of the testing show that the Quantum solution is capable of routinely detecting single or multiple pedestrians or vehicles along or approaching a pipeline right of way. Together, the large awareness envelope provided, the high probability of detection, the greater range for measuring and tracking, and the robust classification algorithms combine to provide security teams with the timely information they need to monitor and secure very large swaths of pipeline efficiently and effectively. The barriers of traditional detection tools are quickly broken down, increasing their ability to deter attacks and/or respond with the appropriate level of action in a timely fashion.

The scenarios examined here are centered on a natural gas pipeline application. This report could as well have focused on other midstream, downstream or upstream asset monitoring applications to include:

- Equipment storage and construction raw material staging yards
- Pump and compressor stations
- Detecting hot-taping of pipelines
- Well heads and rigs
- Above and underground storage facilities, and
- Refineries.

ABOUT QUANTUM

Quantum Technology Sciences is dedicated to providing the most advanced movement monitoring & intrusion detection solutions on the market today. Quantum uses their expertise to provide the oil and gas industry security and surveillance solutions to enhance the safety and security of its customers and the materials, equipment, and infrastructure that they value. Whether in the upstream, midstream, or downstream sector, Quantum's systems provide the awareness necessary for taking proactive action to deter potential threats near security perimeters.

The Quantum solutions do not require a line of sight to "see" through visual obstructions such as topography, trees, fog, and darkness. Extremely advanced algorithms decode ground vibrations, providing an intelligence that automatically and in real-time detects, classifies, locates and reports on threats. The all-in-one system is buried and is virtually undetectable, providing previously unobtainable awareness for valuable Oil and Gas infrastructure locations.

NOTE: We continuously improve our technology. Any product specifications referenced in this document are subject to change without notice.