ODYSSIAN TECHNOLOGY
A Technology Development and Innovation Company

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FINAL REPORT

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SBIR PHASE I

"**Smart Pipeline Network – Cased Pipe for Monitoring and Sensor System**"

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Final Report

SBIR PHASE I

1.0 PHASE I PROGRAM INTRODUCTION

Leak detection within the national pipeline network has long been recognized as a much-needed capability to reduce the loss of high value product, improve public safety, and to reduce the emissions of environmentally damaging substances.

In recent years, greater emphasis has been placed on the reduction of green house gas emissions in an attempt to address global warming. Natural gas contains a high concentration of methane gas, which is one of the most potent green house gas elements. Leakage of toxic and hazardous liquids into the environment often results in the long term contamination of ground soil, and in some cases, results in the contamination of aquifers and waterways that are key to sustaining the local habitat. Consequently, the U.S. Department of Transportation (DOT) Pipeline and Hazardous Materials Safety Administration (PHMSA), as well as various industry associations such as the Pipeline Research Council International (PRCI), have embarked upon extensive research and development programs aimed at establishing capability to pin point the location of pipeline leakage in real time.

Multiple technologies are being explored that offer various levels of leak detection capability, each with its own set of limitations. Aerial surveillance using advanced optical and computational techniques is being developed. This technology indirectly detects leaks by identifying plumes of airborne dispersed particles using LIDAR (Laser Imaging Detection and Ranging) systems and by detecting resulting vegetation damage using hyper spectral image analysis, that can occur as soon as two weeks after the leak begins. While one could focus on the shortcomings of each technology including the negative effects of cloud and snow cover, Odyssian Technology believes that the correct approach to eradicating or significantly reducing pipeline leaks is a *smart pipeline system* that has a collection of diverse (and evolving) technologies all integrated within a distributed, yet common communication and control platform.

Odyssian Technology was awarded programs for submitted proposals to all three of the DOT PHMSA SBIR topics (in solicitation DTRT57-12-R-SBIR1) to allow for development of a comprehensive set of technologies that will be needed to realize a national smart pipeline system. Technology that is unique to Odyssian Technology was adapted for point-of-source leak detection and state-of-the-system health monitoring of the pipeline seals, pipe repairs, and cased pipes. The three separately proposed SBIR programs are configured to be independent of each other. Yet each provides an important aspect or component of the integrated *Smart Pipeline Network*. In summary, the three related proposed programs that were awarded are distinguished as follows:

1. Focus Area 1 (PH1) – Seal Sensor System: is to develop smart seals capable of leak progression detection and monitoring proper sealing force.

2. Focus Area 2 (PH2) – Pipe and Repair Sensor System: is to develop concepts for smart pipe and smart pipe repair sensor systems capable of detecting leaks and monitoring structural integrity.
3. Focus Area 3 (PH3) – Cased Pipe for Monitoring & Sensor System: is to develop new casement and internal support structure concepts that will allow for continuous real time monitoring and network communication along the entire length of the cased pipelines.

The technology developed in these PHMSA SBIR programs take advantage of recent technology advances and shifts in affordability of technology to develop and demonstrate what Odyssian believes will be our future national *Smart Pipeline Network*. Such technology advances include the advent of nano-scale and thin and thick film materials in conjunction with micro machining techniques that allow for the development of very small sensors and multifunctional systems having intrinsically embedded sensing functionality. These small devices and materials are being used to develop highly engineered smart systems that are capable of sensing their environment and often responding to such stimulus.

Odyssian Technology has developed smart pipe and smart seal technology, originally targeted for use on airborne high-energy chemical laser systems. This DOT PHMSA SBIR program further developed and adapt this technology for use on pipelines to allow for the pinpoint location of leaks and in some cases emerging leaks (detecting an imminent leak before leakage occurs). The shift in affordability and proliferation of wireless and wired communication networks makes more feasible a S*mart Pipeline Network* that provides real-time operational status of pipeline transmission, distribution, and remote facility systems. Communication and signal conditioning circuitry was developed that is integrated within the system to provide a sensor network capable of pinpointing the location of progressing leaks through fittings, joints, valves, pipe, pipe repairs, etc.

As described in the PH3 Focus Area #3 solicitation, the current configuration of cased pipes present a challenge to using pipeline monitoring technologies. Internal support structures within cased pipe are circumferential, blocking access and impeding utilization of the interior space. As with the smart seal and smart pipe technology, Odyssian Technology is uniquely qualified to develop new cased pipe concepts for use in a smart pipeline system. Odyssian Technology has an active patent on structures having internal (truss) support structures with integrated sensors and electronics. This technology and expertise, which is described in Odyssian Technology's proposal to Focus Area #3, was used to develop cased pipe concepts that support monitoring and integrated pipeline sensing.

In Odyssian Technology's related PHMSA SBIR programs to develop *smart seal* (PH1)and *smart pipe and smart pipe repair* (PH2) technology for the pipeline industry, technology was adapted and further developed that was originally developed for the U.S. Department of Defense (DOD) Missile Defense Agency (MDA). This includes smart piping system technology that was developed for the MDA Airborne Laser (ABL) system to detect leak progression of harmful chemicals that are within the ABL high energy laser system. Such technology includes novel seals and piping that detect impending leaks using highly integrated point-of-source leak detection sensors. A wireless Zigbee sensor network was used to communicate state-of-the-system or containment status of the ABL Smart Piping System. This technology has been developed and demonstrated in a laboratory setting

through funding under MDA Phase I and Phase II Small Business Innovation Research (SBIR) programs.

This PHMSA SBIR focused on the development of a new cased pipe design with internal support structure or spacer that allows access along its entire axial length to make possible the routing of optic fiber, wire, or sensor probes. When combined with the Smart Pipeline Seal Sensor System and Pipe Repair Sensor System (separate but related projects), this technology allows for a comprehensive Smart Pipeline Grid having integrated sensor networks that provide for continuous real-time monitoring of leaks and system health.

This SBIR program developed design concepts for cased pipe spacers that allow pass-through access along longitudinal axis for routing of communication and sensor network cabling. Such access supports wired and wireless transmission of data through the cased pipe spacer channels. This new cased pipe spacer design has *wide application* in both hazardous liquid and natural gas pipeline systems. The Phase I feasibility evaluation focused on developing a cased pipe spacer system for liquid petroleum-based pipeline systems, with secondary consideration given to the incorporation of natural gas sensor systems.

In this program, a design concept were developed for cased pipe spacers that improve monitoring and lends itself to the incorporation of networked sensing system capable of sensing the pinpoint location of a leak, as well as monitoring structural health. In Phase I, Odyssian Technology aligned itself with a manufacturer of cased pipe spacers and focused its effort on expanding a particular commercial cased pipe spacer design to include integrated sensors for use with petroleum-based liquids.

2.0 EXECUTIVE SUMMARY

During the program period of performance, research and development was conducted and design concepts were developed for a cased pipe spacer having integrated leak and impact detection sensors. Odyssian Technology teamed with the Pipeline Research Council International (PRCI) to provide input on the related needs of its pipeline operator membership. To assist with this process, Odyssian Technology in conjunction with PRCI leadership, established the PRCI Smart Pipeline Steering Committee that was made up of representatives from various pipeline operator companies, as well as PRCI staff members. After gaining a better understanding of current methods and construction of cased pipe, as well as the related technology interest of some of the pipeline operators, activity was directed toward developing 'open access' pipe spacer concepts instead of monolithic dual walled smart pipe concepts.

Odyssian Technology started by researching and evaluated commercially available cased pipe spacer systems. It was learned through this research that cased pipe spacers with open axial access were commercially, requiring only a modification of existing spacer systems to introduce leak and impact detection sensors. Near the beginning of the program, Odyssian Technology established a business relationship with an international provider of cased pipe spacers. This company assigned personnel to assist Odyssian Technology in evaluating their open-access spacers for use as a baseline from which to develop a smart cased pipe spacer. A metallic spacer for a 4" steel pipe was selected

for use in developing a smart cased pipe spacer. Odyssian Technology developed the electronic circuitry and software to convert this selected spacer into a networkable cased pipe spacers having integrated leak and impact detection sensors.

3.0 SUMMARY OF WORK PERFORMED

This program included the following tasks. A summary of work performed under each task is provided in the subsequent subsections.

The work plan of this program included the following four tasks;

Task I – Application and Concept Study

Task II – R&D, Prototype, and Lab Scale Evaluation

Task III – In-field Evaluation Planning

Task IV – Preliminary Cost and Market Analysis

Task V – Program Management & Reporting

Task I – Application and Concept Study

The Pipeline Research Council International (PRCI) in conjunction with Odyssian Technology established the Smart Pipeline Steering Committee, which was made up of several PRCI members to provide support to this SBIR program. This committee, which was made up of key PRCI members who could eventually be users of the Smart Pipeline Network, was formed to provide assistance in identifying applications for the smart pipeline technology, to identify potential issues , and to review concepts. During the Application Study with PRCI members, a broad system level approach was taken that considered the cased pipe for smart pipeline (this program's focus), as well as the related sensor seal and pipe & repair applications (other related SBIR programs).

APPLICATION STUDY

During the Application Study, multiple discussions were held with PRCI staff and members on the need for leak detection and the areas of greatest opportunity. Below is a list of some of the application concepts that were identified during these discussions

1. ISOLATED CASED PIPE SPACERS – Development of cased pipe spacers that not only provide full axial access for routing optical fiber, wires, probes, etc, but also provides voltage isolation of the carrier pipe.
2. STRUCTURAL CASED PIPE SPACEERS – Interest was expressed in seeing the development of smart pipe spacers for use with larger transmission pipes that carry relatively high force loads. These smart spacers would be more structural than the non-metallic voltage isolation spacers.
3. EXPLOSION PREVENTING CASED PIPE SPACERS – There is a need for cased pipe spacers having embedded sensors that can detect the leakage or buildup of

explosive substances. During this program a cased pipe explosion occurred due to the leakage of natural gas from the carrier pipe.

4. ENCASED INSULATED PIPE SPACER – There is an interest in developing dual walled pipe having embedded sensors, where the outer wall is an encasement that shields insulation from the weather. The embedded sensor network would detect moisture intrusion and monitor pipe temperature and insulation performance. This need could be met by developing spacers having embedded sensors that are designed to secure insulation jackets.
5. FLANGE LEAK DETECTION – Development of seals for flanged connections having embedded leak detection sensors that are part of a sensor network.
6. FLANGE TORQUE SENSING – Development of flange seals having sealing force sensing capability that verifies proper tightening of the bolts. It has been stated that a majority of leaks across flange seals is the result of improper installation and tightening.
7. PIPE COATING SENSING – Development of embedded sensor networks that monitor the integrity of pipe coatings and heat-shrinkable sleeves used to cover uncoated portions of the pipe having welded joints.
8. HYDROGEN SULFIDE – Development of small embedded sensing technology that is capable of detecting leakage of Hydrogen Sulfide (H_2S) across seals. H_2S is a colorless and very poisonous flammable gas.
9. WATER CROSSING – There is a need to monitor water crossing pipe due to the high consequence of failure. Interest was expressed to develop a water crossing smart piping system that can detect impacts from debris and pipe rising, which can occur during flooding.
10. COMPOSITE WRAP REPAIR SENSING – Develop a way to monitor the sealing and structural contribution of composite wrap repairs. The sensorSLEEVE™ developed during this program could house strain and leak detection sensors to monitor composite repair. In this application, the sensorSLEEVE shell would not have to be designed to be a secondary containment structure because of the presence of the composite wrap repair. The shell would be a lower cost and lower weight design that only provides an electronic enclosure to shield the sensor circuitry and to be a collector of leaking substance to ensure contact with the sensors.
11. SMART MECHANICAL SEAL – Develop a mechanical seal for use in compressor and pump stations that detects leaks and monitors the health of the bearings by measuring vibration levels.
12. SMART WELL-SITE SEALS – Develop sensor system that is highly integrated within the well-site piping system to monitor temperature, strain, and containment.
13. SMART ISOLATION GASKETS – Develop flange isolation gaskets with embedded leak detection sensors for use on cathodically protected piping systems. Particular interest in using on flanged isolation fittings that are in remote areas where leaks may go undetected.
14. SMART ELASTOMERIC SEALING – Further develop elastomeric material and algorithms that can be used to sense sealing force. This technology was invented by

Odyssian Technology for use in elastomeric O-rings (patent pending). Characterize behavior and performance of various forms.

15. NATURAL GAS – Interest was expressed in seals having natural gas leak detection. It was learned that the leakage of natural gas is the prevalent of all leaking substances. Develop smart seals for natural gas that are wireless for easier installation in facilities and plants that have a large number of seals.

The results of the application study are summarized in Figure 1. As shown, this project focused on developing leak and impact detection for pipeline systems containing refined petroleum product, specifically gasoline. The application was initially defined to be long run transmission pipelines. PRCI members expressed a desire for leak detection within facilities near the end of the program. The smart cased pipe technology developed during this program is intended for use outside facilities, but much of the associated technology including the sensor network, cloud based controls, smart seals, and smart pipe would be very useful for leak detection and health monitoring within pipeline facilities. Also shown in Figure 1, is the selection of components or subsystems that would be part of the initial smart pipeline prototype system. The components selected for the prototype system include; (1) smart seals for use in flanged fittings, (2) smart sensor-spacers for use in cased pipe, and (3) sensor-boots or sensor sleeves for use over repaired pipe, fittings, valves, welded joints, etc. The product selected for leak detection is refined liquid petroleum product, specifically gasoline.

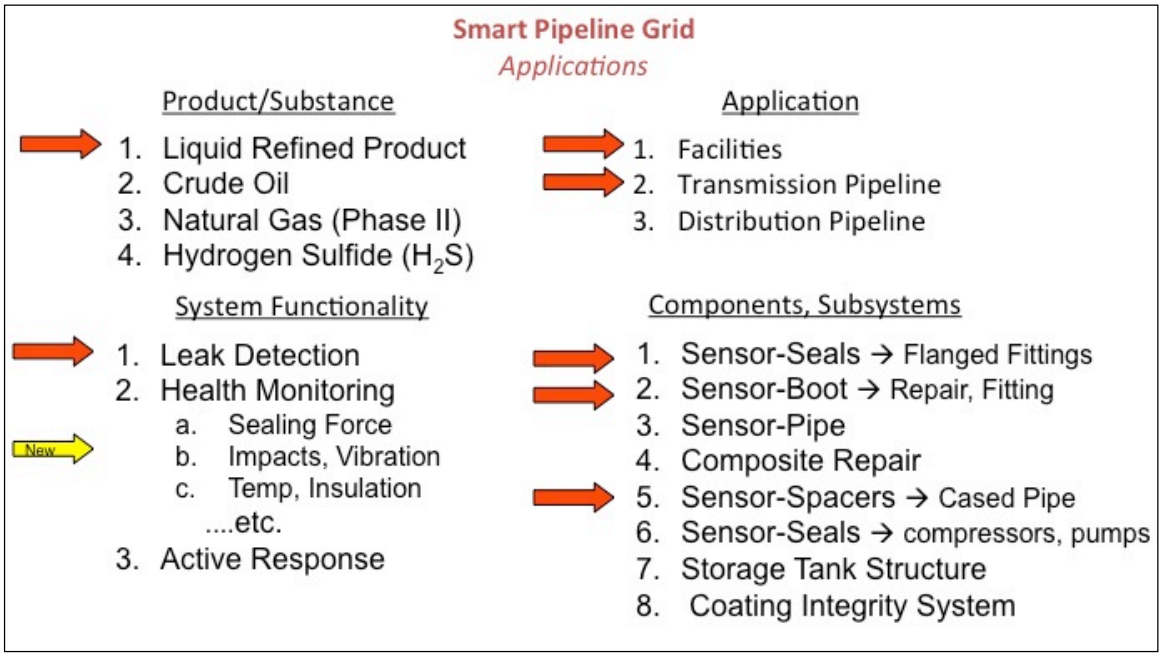


Figure 1 – Odyssian Technology and the PRCI Smart Pipeline Steering Committee defined the scope of the application, product to be contained, functionality of sensor system, and what type of components would be further developed and demonstrated.

CONCEPT STUDY – CASED PIPE

During this program, research was conducted into existing cased pipe and related cased pipe spacers. It was found that products are on the market for spacers that provide open access along the axial direction, as needed for wired or wireless connection of the sensor network. These commercial-off-the-shelf spacers do not have the sensor suites integrated within the spacers. Consequently, the initial concept development effort started by developing a conceptual design of a smart spacer that is a modification of existing spacer designs with open axial access. This conceptual design, which is shown in Figure 2, includes four runners or feet with two halves that are bolted together.

During this portion of the program, Odyssian Technology established a relationship with Garlock Pipeline Technology (GPT) to collaborate on the development of smart cased pipe spacers. The design concept that is shown in Figure 2 is very similar in construction to a spacer that GPT currently sells commercially. This commercial spacer is shown in Figure 3.

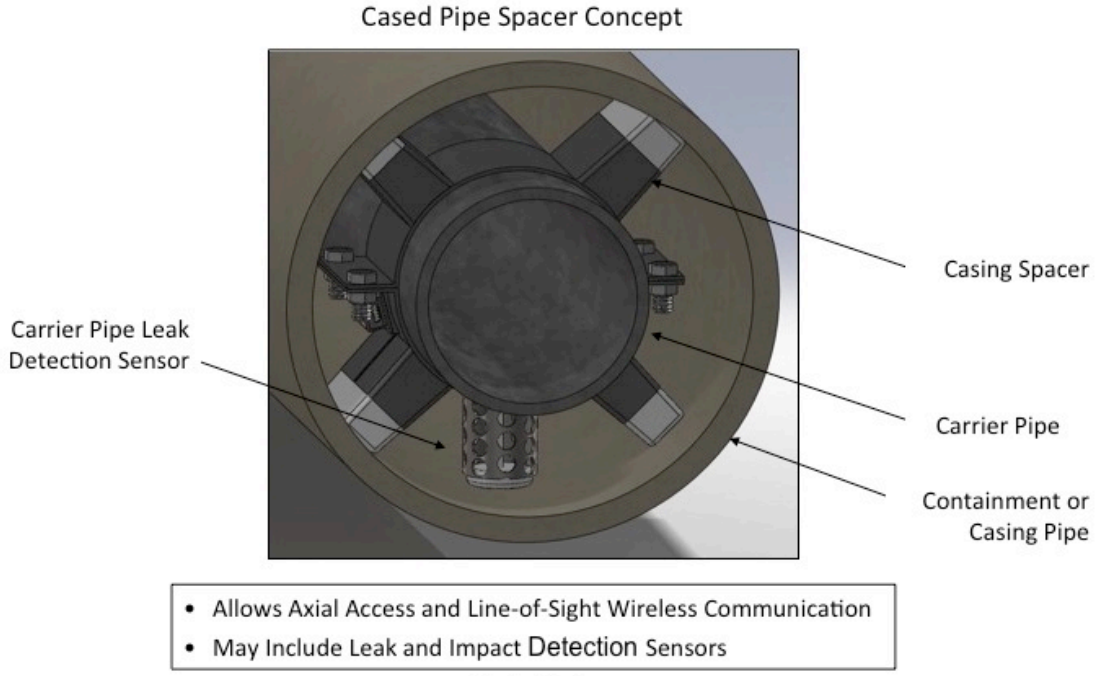


Figure 2: Smart Cased Pipe Conceptual Design. This design concept integrates sensors into a cased pipe spacer having voltage isolation. Shown is a concept that a sensor enclosure that includes a float valve to detect the accumulation of liquid, as well as providing space for other sensors such as an accelerometer, natural gas sensor, crude oil sensor, or gasoline sensor.

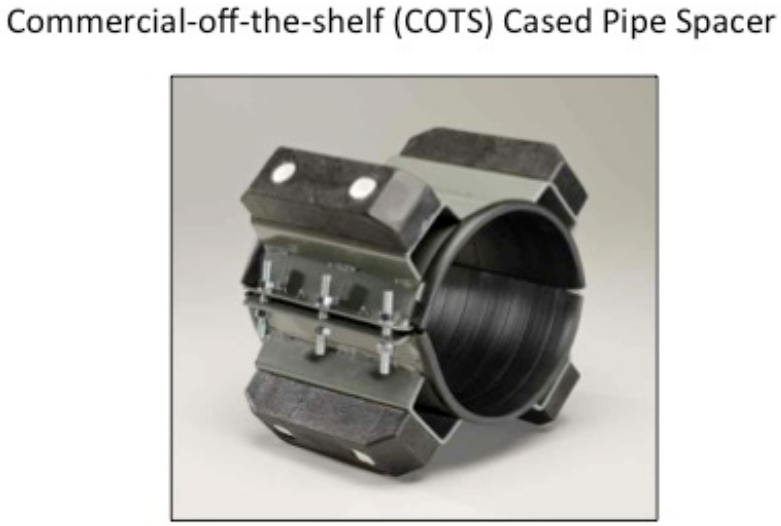


Figure 3: Cased Pipe Spacer made by Garlock Pipeline Technology (GPT). This voltage isolation spacer was selected for modification to develop the sensorSPACER™ having leak and impact detection sensors. This spacer is similar to the spacer design concept developed early in the program.

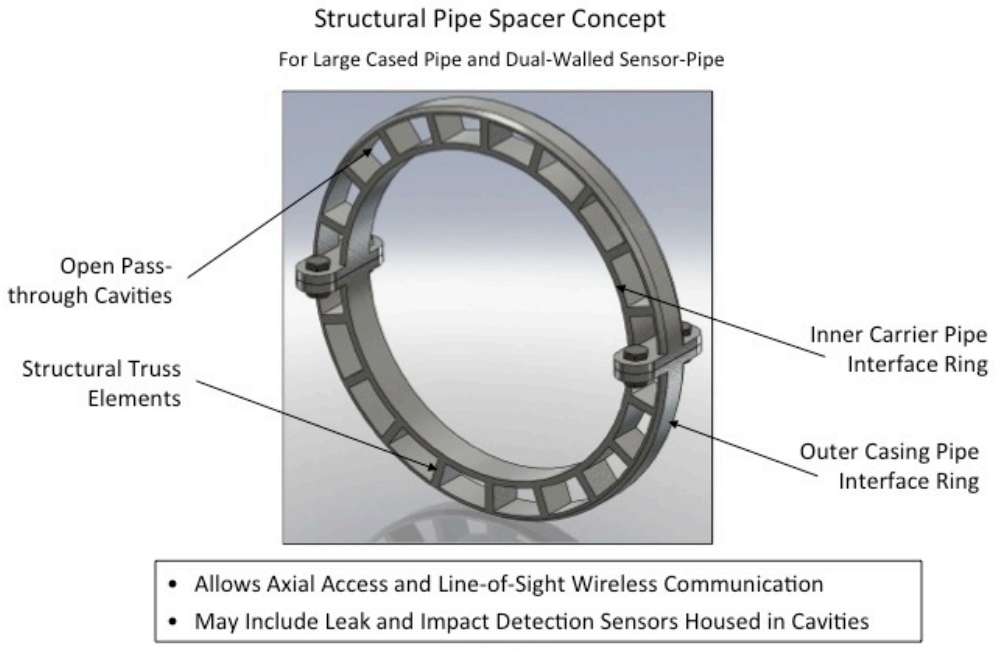


Figure 4: Shown is a design concept for a cased pipe spacer for use on large transmission cased piping. This design uses machined steel in place of the plastic and formed sheet metal in the other spacer concept. It is intended for applications where the force loads are relatively high.

During the concept study, the PRCI Smart Pipeline Steering Committee asked that we develop a design concept for a cased pipe spacer that could be used on large transmission pipes measuring 30" in diameter or larger. Figure 4 shows a design concept for such a spacer. As shown the annular space is kept accessible by using structural truss elements that provide open pass-through cavities. This design is intended to make full contact between the outer cased pipe and inner carrier pipe to distribute and share force loads across both pipes. The open cavities provide an area to house sensor circuitry, as well as provide open axial access for wired and line-of-sight wireless connectivity.

CONCEPT STUDY – NETWORK TOPOGRAPHY

A conceptual design of the network topography was developed for a long run pipeline having impressed current cathodic protection (ICCP). This topography, which is shown in Figure 5, has a two level network topography that includes multiple lower level microprocessor-based sensor networks integrated to a higher level TCP/IP – based network. The microprocessor-based sensor networks communicate via a wired network using a controller area network (CAN) protocol or via a wireless network using the Zigbee® protocol. The network topography design is for a voltage-isolated section of piping having a rectifier station for its impressed current cathodic protection (ICCP) system and a flanged fitting having with a smart voltage-isolating gasket.

Each 40 foot pipe segments has a sensor node (sNode) to support all sensor circuits associated with its pipe segment. The sNodes provide signal processing and conditioning and have a micro controller, CAN controller, and wireless modules to support networked data communication to the integration node (iNode). Each microprocessor-based sensor network has multiple sNodes that communicate to one supervisory iNode. The iNodes are the master controllers on the sensor networks and are coupled to a single board computer (SBC) to provide connectivity between the lower level microprocessor-based sensor network and the upper level TCP/IP network. The iNodes have multiple responsibilities including communicating to the multiple sNodes that are a part of its lower level microprocessor network, as well as controlling data handling and transfer between the SBC and the sNodes. The SBC's of each sensor network is responsible for communication to a cloud-based host server and for providing local data storage and management, as well as providing the option to connect locally to the sensor network associated with the SBC. When connected locally a computer device, such as a laptop or smart phone, plugs into the SBC via an Ethernet cable to establish a peer-to-peer connection to the SBC. The webpage of the SBC are accessed much like other internet devices (i.e., routers, wireless access points, etc.) by entering the unique SBC Internet Protocol (IP) address into the address line of a web browser, such as Internet Explorer or Fire Fox.

The energy source needed to power the network comes from the same energy source that feeds the Rectifier Station. Rechargeable batteries are used to provide back up power in the event of lost power. The design includes both wired and wireless networked communication. Similar to security systems, the smart pipeline will operate over a wired network and the wireless networked communication will be used only when connectivity of the wired network is lost.

This particular design shows sensors embedded within heat shrinkable sleeves that go over the welded joints of long run pipelines. These sensors monitor the integrity of the sleeve and pipe.

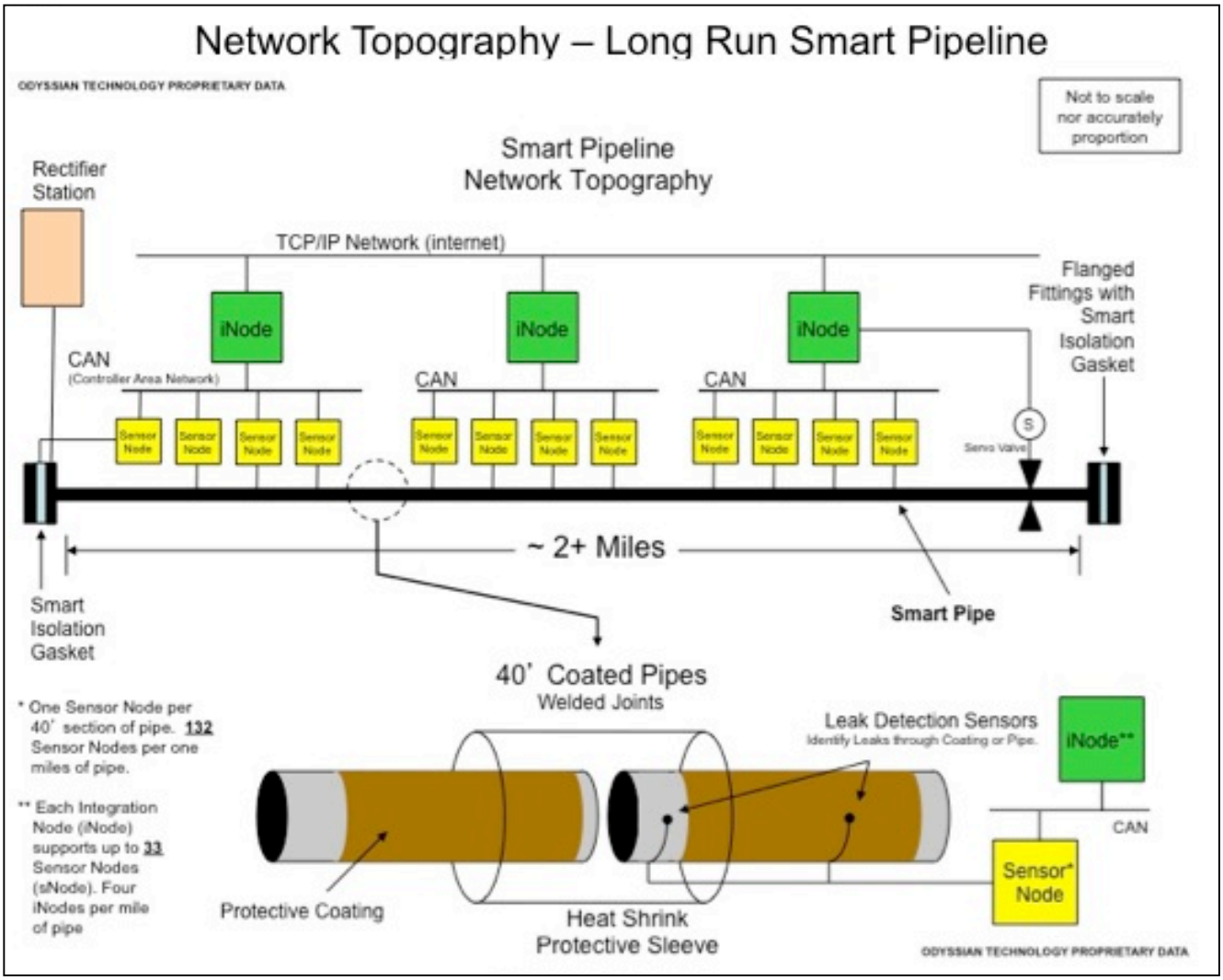


Figure 5: Network Topography Concept. This concept was developed to help communicate to the PRCI Smart Pipeline Steering Committee how a smart pipeline network could be set up for long run pipeline applications. Shown is a topography that includes multiple sensor area networks made up of a master node or integration node (iNode) that serves up to 33 sensor nodes (sNodes). The sensor area networks are integrated via a TCP/IP (internet) network.

Task II – R&D, Prototype, and Lab Scale Evaluation

SENSOR RESEARCH AND DEVELOPMENT

Odyssian Technology choose to further develop and prototype a smart cased pipe spacer having sensors that detect an impact and the leakage of gasoline from the carrier pipe. To accomplish this Odyssian Technology enhanced a reactive fuel sensor that it had developed years earlier. The reactive sensor was modified to be mountable to a printed circuit board (PCB) and packaged for improved containment of the sensing element. Figure 6 shows three test sensors that are mounted to a small PCB having connection leads. These specimens were tested by exposing them to mid-grade unleaded gasoline while taking electrical readings using the multimeter shown in the figure.

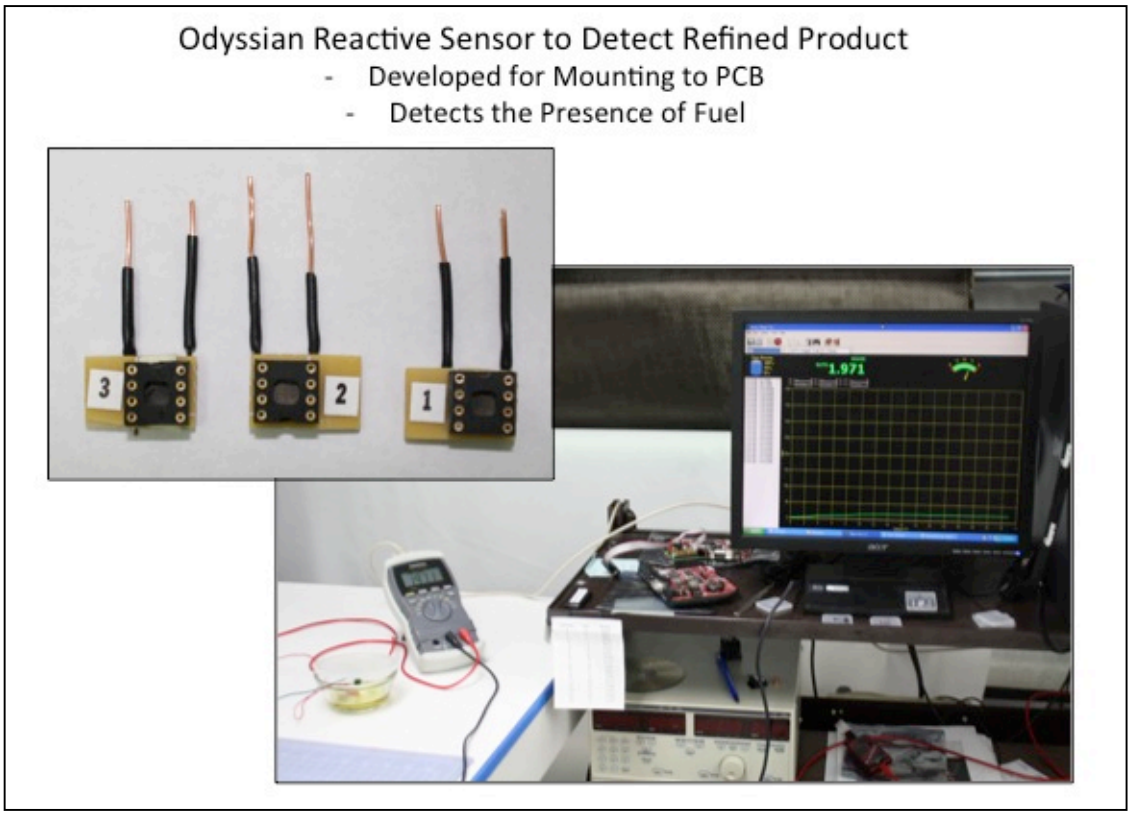


Figure 6: Odyssian Technology's Reactive Gasoline Sensor and initial test set-up. Odyssian Technology developed a sensor that detects the presence of gasoline and other hydrocarbons. During this program this sensor was further improved upon by making it mountable to a printed circuit board. Shown are three sensor test specimens and the initial test set-up used to test and verify sensor response.

Testing included exposing the reactive fuel sensor to gasoline vapor, to a single drop of liquid gasoline, and then completely saturating the sensor in liquid gasoline. The results showed a noticeable response when exposed to vapor and extreme responses when exposed to a single drop and when saturated. Figure 7 shows the response of the fuel sensor when saturated in gasoline. As shown, the sensor reaches 1M Ohm resistance in a little over 8 minutes. Figure 8 shows the response of the sensor when exposed to gasoline vapor. This data shows a significant response is achieved over a longer period of time. Testing showed that the sensor's first 'at-rest' (no gasoline present) electrical signature is different then the at-rest electrical signature of the sensor after it had been exposed to gasoline This showed that there is a need to condition the sensor by exposing it to gasoline prior to its first use. Testing also included exposing the reactive sensor to other hydrocarbons and it was found that the sensors are capable of detecting a few of these other hydrocarbons. This testing is inconclusive and requires further research.

Lab evaluations included observing if there was a noticeable change in the reactive sensor's sensing element after repeated exposure to gasoline. Visual inspection suggests that the element may be used multiple times without noticeable degradation, but further testing is needed to conclusively determine the useful life of the sensor.

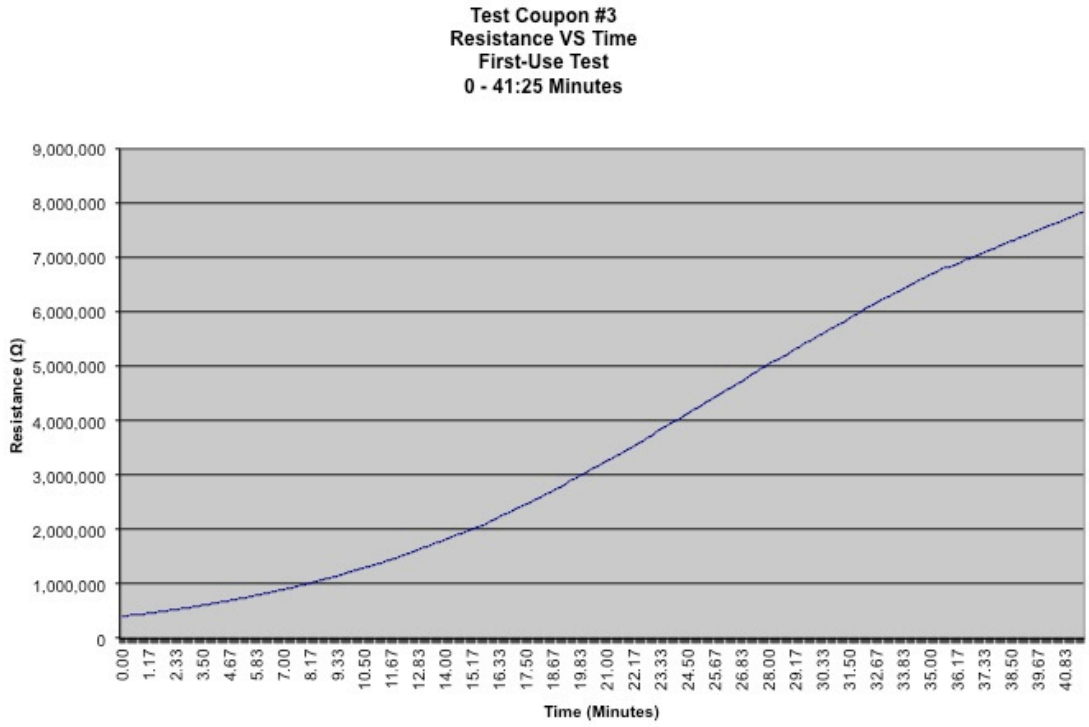


Figure 7: Odyssian Technology has developed a proprietary multi-use sensor that responds to the presence of various hydrocarbon based substances including gasoline. Further research is needed to understand what the sensor capable of sensing under various conditions, as well as to understand the repeated performance of the sensor over its determined life.

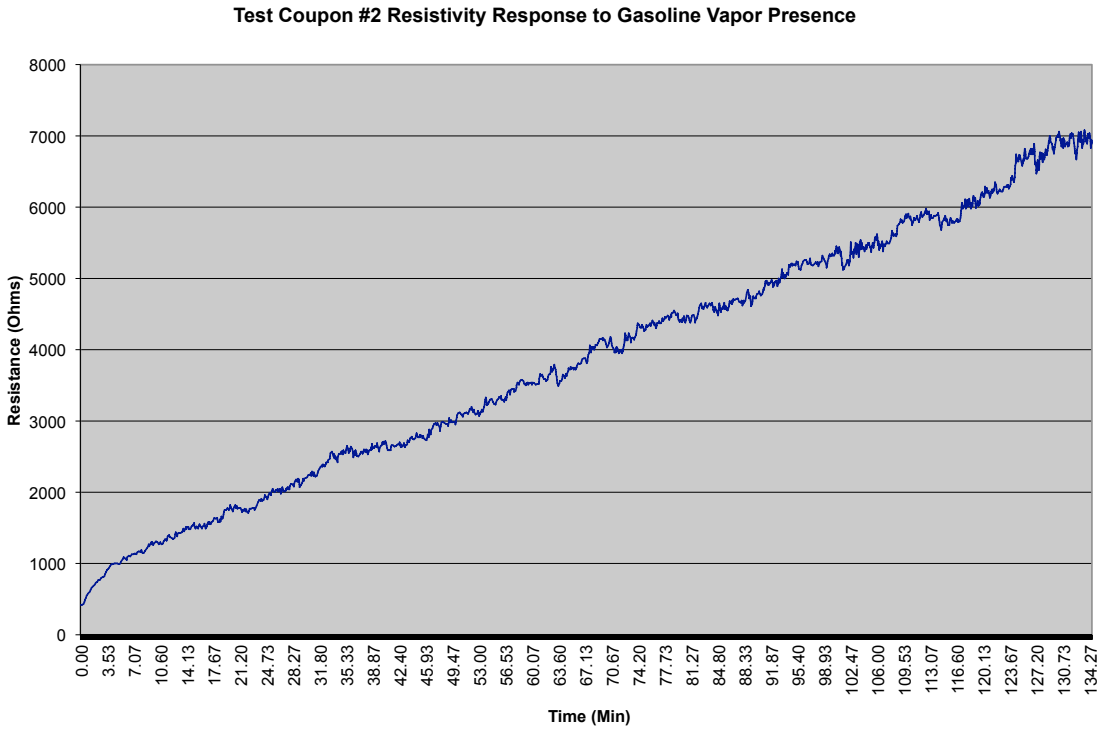


Figure 8: Shown is the response of Odyssian's reactive fuel sensor when exposed to gasoline vapor over time. This data implies that this sensor technology would be able to sense a gasoline leak without coming into contact with liquid gasoline. Additional characterization and formulation optimization is required to complete development of the sensor system.

The prototype of the smart cased pipe spacer used commercially available accelerometers to detect impacts on the carrier or cased pipe and to detect potentially damaging earth movement. The photographs in Figure 9 show two accelerometers that were used in the smart pipeline network prototypes, which includes the smart cased pipe spacer developed under this program as well as the smart seal and sensor boot (sleeve) developed under the other two related Smart Pipeline Network SBIR programs. The accelerometer shown on the left was used in the smart spacer (a.k.a sensorSPACER™) and the smart seal (a.k.a. sensorSEAL™) and the accelerometer shown on the right was used in the sensor boot (a.k.a. sensorSLEEVE™). A switch was made to the accelerometer on the right because it was considerably less expensive at low volumes than the accelerometer shown on the left.

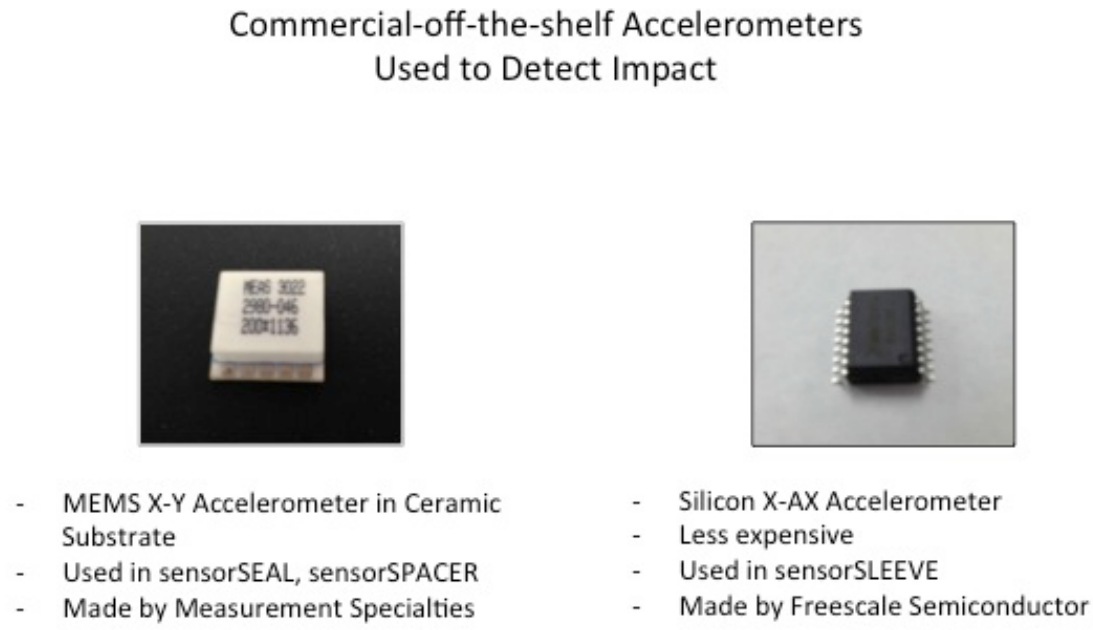


Figure 9: Commercial –off-the-shelf accelerometers were used to detect impact and earth movement. The accelerometer shown on the left is a more expensive MEMS accelerometer capable of detecting vibration in the x and y directions.

PROTOTYPE SYSTEM DEVELOPMENT

A smart cased pipe was developed and prototyped called the sensorSPACER™ . The sensorSPACER is a component of the Smart Pipeline Network that is made of a cased pipe spacer having sensors to detect leaks and undesired vibrations within a cased pipe. An example of the need for such a system was made evident during performance of this program when a cased pipe exploded in West Virginia due to a leak within a carrier pipe that was containing Natural Gas. This explosion shown in the adjacent photograph is covered in the NPR article at: http://www.npr.org/blogs/thetwo-way/2012/12/13/167169109/no-alarm-sounded-when-the-west-virginia-pipeline-exploded) .

The smart pipeline network system, which is referred to as the sensorPIPELINE™ , includes a cloud-based controller that is capable of monitoring a large collection of sensor networks. Such a system will ultimately be a provide real time monitoring of the pipeline systems, both long run O&G pipeline and discrete O&G pipeline facility piping systems. Figure 10 shows a schematic of a notional cloud based system that is capable of monitoring large pipeline installations. It is envisioned that this system, which takes advantage of the internet infrastructure, will be a non-biased service that monitors the integrity of our nations pipeline system. As shown in Figure 10, this system will service multiple control centers made up of both private and government entities. The sensorPIPELINE system will have a control architecture involving lower level sensor networks that are integrated within higher level internet networks. In the event of lost connectivity the sensor networks will continue to collect status data at the local level. Once connectivity is regained, the master data bases within the internet network will be updated with status data that occurred during the lost connection. As shown, each sensor network is made up of multiple sensor nodes (a.ka. sNodes) that connect to the various sensor components within the network. The sNodes within each of the sensor networks communicates to a master node, referred to as an integration node (a.k.a. iNode), which is coupled to a single board computer (SBC). This iNode/SBC acts as the local data management device and provides a gateway to the TCP/IP internet network.

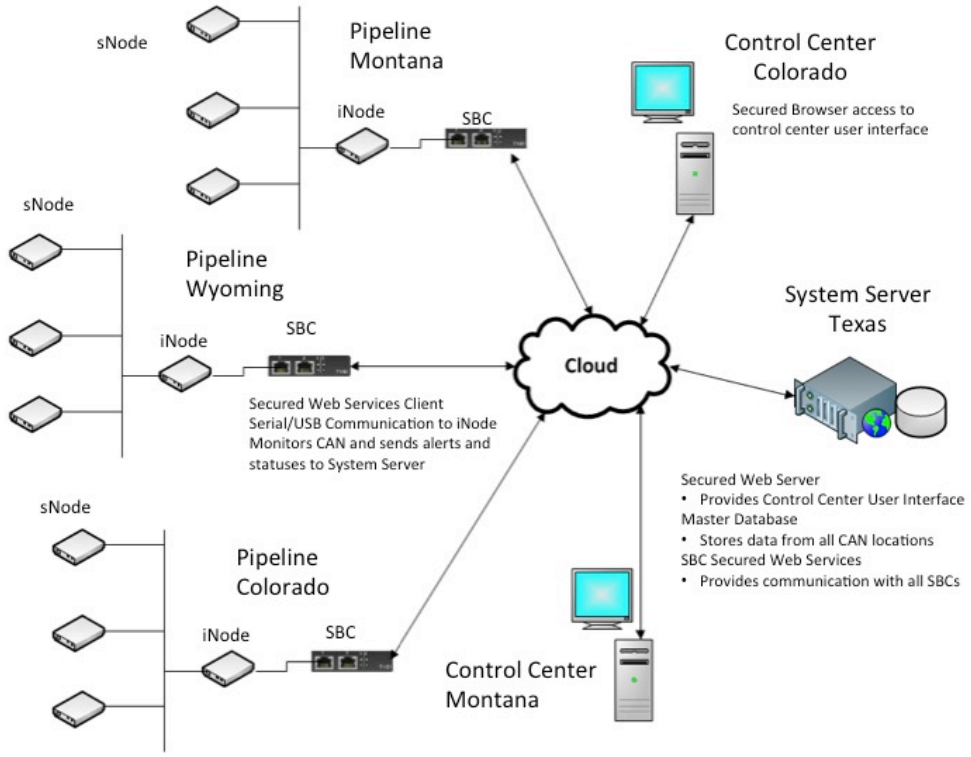


Figure 10: Topography of the sensorPIPELINE™ Network. As shown, the sensorPIPELINE™ system has web-based controls.

sensorPIPELINE Subnet Server

The purpose of the iNode/SBC (a.k.a Subnet Server) is to configure and control the sensorPIPELINE CAN network. The Subnet Server is also responsible for managing local storage of data and for transferring sensor data to the centralized cloud database. A Subnet Server is a small credit card size single board computer (SBC) utilizing a low power ARM8 processor. The SBC has serial port communication capability to the CAN (controller area network) sensor network and TCP/IP access to the Internet. The SBC runs a version of Linux called Ubuntu and is configured with a MySQL database engine for local data storage.

A control and communication software application written in C was developed to manage the serial communication with the CAN sensor network. The C application sends configuration commands to the CAN network and receives back sensor state data that is both stored locally in the MySQL database and forwarded onto the centralized database in the cloud. Communication with the cloud is through REST style web service calls. The C application makes secured https/ssl web service calls to the sensorPIPELINE centralized cloud system utilizing a Linux library called cURL. Through this web service interface the C application receives configuration information and sends out sensor data.

During normal operation the C application simply receives a continuous stream of sensor data from the CAN network, performs sensor specific data conversions, determines status of each sensor (normal, caution, or alarm), locally stores the sensor data and then forwards the sensor data to the cloud in real time. The normal operating mode of the C application can be interrupted by commands placed in its processing queue in the cloud. The C application periodically queries the cloud though the web service interface for new commands to execute. Any new commands found are executed and when there are no more commands in the queue the C application will return to the normal mode of receiving a continuous stream of sensor data.

The C application stores the last configuration commands and other state information so that in case of local power loss the system can return to the last operating state when power is restored. In addition, the C application continues to operate even if communication with the cloud is lost or interrupted. Any sensor data stored locally will be sent onto the cloud system when Internet communication is restored.

sensorPIPELINE Cloud System

The purpose of the cloud system is to report on the health status of the overall system, to report on the status of individual CAN sensor networks through their local Subnet Server, manage the configuration of all devices within the system, and to store sensor history data sent from the installed base of Subnet Servers. There are two types of software applications in the cloud, the web user interface and the REST style web services.

The purpose of the web user interface is to provide users with:

- A quick means of monitoring overall system health
- The ability to monitor the state of specific SubNet Servers
- A mechanism to configure all devices within the sensorPIPELINE system
- Mapping capabilities to assist in locating specific devices within the system

- A means to review and export sensor history data

The web interface is designed to be accessed by web browsers such as Internet Explorer, Chrome, Safari, and Firefox. The web user interface allows access to system features through secured https/ssl communication. The web interface is written primarily in PHP, jQuery, and CSS. It features secured login authentication and uses roles to give individual users controlled access to specific features of the system. Navigation through the web interface is designed to be simple allowing the user to quickly see the state of the system and if required take action when the system is in the caution or alarm state. Mapping features make use of the Google Maps jQuery API.

The other software developed for the cloud is the REST style web services interface allowing machine-to-machine communication between the cloud and each installed Subnet Server. The web service interface is also accessed through secured https/ssl communication. Each Subnet Server is uniquely identified and access to the web services requires secured login authentication. The Subnet Servers use the web services interface to retrieved commands and configuration data and to send sensor history data to the cloud for long term storage. The web services interface is also written in PHP and messages are passed in JSON format.

Both the user web interface and the web services utilize a MySQL database for storage of data and the Apache2 web server. The current system runs within a Linux operating system known as Ubuntu. The components of the cloud system are designed to work with other common cloud services for load balancing and scaling so as the system grows in size it is easy to add resources to handle demand. In addition the design of the system allows for the use of virtual cloud resources and allows for easy maintenance, backup and recovery options.

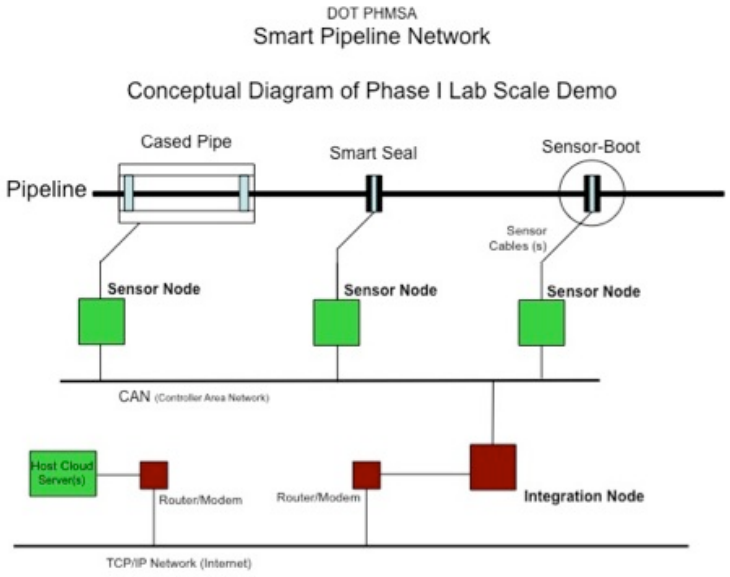


Figure 11: Topography of the Prototype Network.

To demonstrate the sensorPIPELINE a prototype was designed and developed that includes the web-based controls for the full operational system. Figure 11 shows a schematic of the prototype demonstration system and its components. The difference between this prototype and the full system

is the limited number of sNodes and attached smart components. The demonstration system includes only a smart spacer or sensorSPACER that was developed under this program, a smart seal or sensorSEAL, and a sensor boot or sensorSLEEVE.

sensorSPACER component

The sensorSPACER is a modification of a cased pipe spacer that is currently manufactured by Garlock Pipeline Technology, an operating business unit of EnPro Industries. Under this program, Garlock collaborated with Odyssian to develop both the smart spacer and the smart seal components of the sensorPIPELINE system. This collaboration is expected to ultimately result in Garlock commercializing this technology. Both the smart spacer and seal are derivatives of seal and spacer products currently manufactured and sold by Garlock Pipeline Technology (GPT).

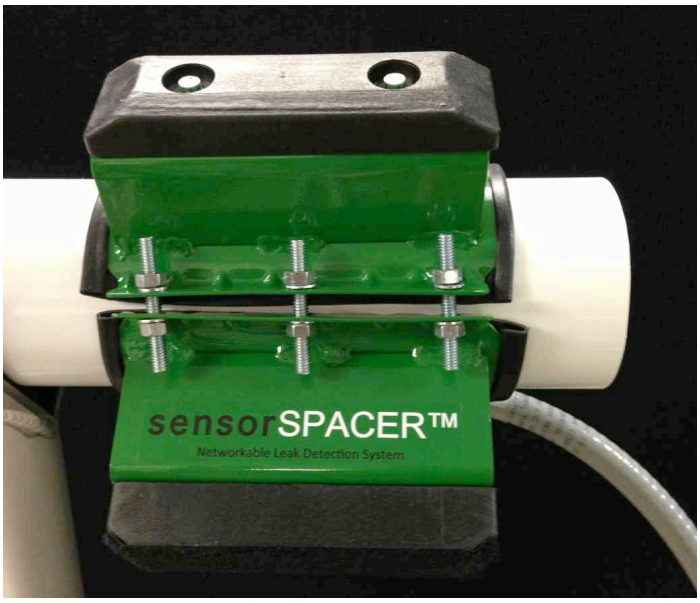
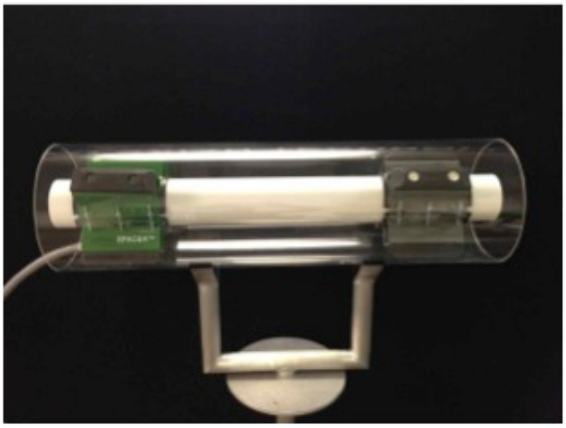
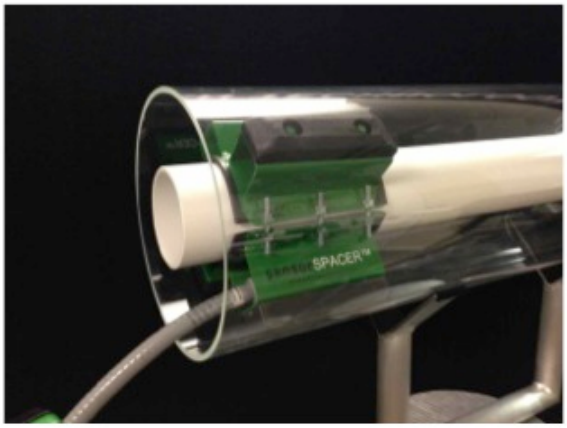


Figure 12: Photograph of the Prototype sensorSPACER™. This spacer is a modification of the commercial Garlock commercial spacer with sensors added to detect impact and gasoline leakage. The figure shows a conduit that encases the sensor harness. The sensor harness is the cable that connects the sensor PCB to the sensor node (sNode). The sensor suite is located within the foot of the spacer and includes an enclosed sensor PCB having a fuel and an accelerometer sensor.





The photograph in Figure 12 shows the sensorSPACER that was developed and prototyped in this program. As shown, this spacer is a two piece voltage isolation spacer that is used on 4" OD steel piping. The modification included the addition of Odyssian's gasoline sensor and a commercial-off –the-shelf accelerometer sensor to detect impact and earth movement. This sensor suite was integrated into a local area sensor network that is tied to the cloud host server via the Subnet server (iNode/SBC controls).

Task III – In-field Evaluation Planning

The in-field evaluation plan includes those activities that are believed to be necessary to validate this technology in an operational setting. To adequately validate this technology the following activities are required;

1. Continue to characterize the sensor suite to better understand the performance limits
2. Conduct in-field site surveys to better understand the operational environment and installation implications.
3. Select a demonstration site that is a cased pipe modification or new installation located in an area with adequate physical access and internet connectivity that would be needed for prolonged system monitoring and evaluation.
4. Fabricate and install a sensorSPACER system within the selected site.
5. Perform and report prolonged system performance testing and evaluation results.

It is preferred that this in-field evaluation be performed on an operational system. But, if pipeline operators are unwilling or unable to provide access to such a cased pipe then the contingency is to simulate such an environment by installing a smart cased pipe in a controlled area, such as at Odyssian Technology's research facility, Stress Engineering's test sight, or other available test facility that is recommended by the PHMSA customer.

Task IV – Preliminary Cost and Market Analysis

Current system estimates are based on prototype cost at minimum order and developmental cost. Projected Future Cost Estimates assume large quantity orders and reduced engineering time. Installation and maintenance costs have not been adequately estimated due to lack of incurred cost history. These numbers will be formulated during the in-field evaluation.

Smart Pipeline Network - Cased Pipe for Monitoring and Sensor System	
Current Cost Estimates	Projected Future Cost Estimates
$4,673.78	$2,336.89

To provide a non-biased assessment of the market potential a third party was contracted to perform the preliminary market analysis. The third party selected to conduct the Phase I SBIR market analysis was Dawnbreaker, Inc. . A lengthy comprehensive report was delivered at the conclusion of this market analysis and is available for review. The following is an executive summary of this report.

Market Analysis Summary

Odyssian Technology has developed a set of technologies for application in the oil and gas pipeline industry referred to sensorPIPELINE which includes: (1) sensorSLEEVE, (2) sensorSEAL, and (3) sensorSLEEVE. A comprehensive preliminary market analysis was conducted and is available in a separate report that identifies potential target markets for these technologies by assessing competing technologies, and by providing data that would assist in understanding how to penetrate the Oil and Gas industry. Sources of potential funding for continued technology development are also identified. The following is an executive summary of the full market analysis.

Leak Detection Systems

In the Oil and Gas industry, the market opportunity for leak detection exists because of a number of federal regulations. Most recently, the Pipeline Safety Improvement Act of 2006 encouraged the continued study of pipeline safety and security practices and mandated a leak detection study. In 2007, this study was commissioned by the U.S. Department of Transportation Pipeline and Hazardous Materials Safety Administration (PHMSA) and was issued in 2012 as the Leak Detection Study. Three types of leak detection systems (LDS) were defined and categorized in this report: (1) visual inspection techniques; (2) instrumented monitoring of internal pipeline conditions; and (3) external, instrumentation for detecting leaked hydrocarbons. The comprehensive study defines a leak detection system (LDS) as having three components, all of which must be considered: Personnel, Procedures, and Technologies.

According to operators, "false alarms" are a major concern and are not the result of the LDS not functioning properly. False alarms reflect the fact that normal operational changes on or near the pipeline can cause exactly the same physical effects that the LDS uses to detect leaks. "It is an inherent difficulty with any technology that relies upon any physical side effect of a leak for its detection." Another issue mentioned was that external systems are often quite complex and are difficult to select, engineer, and deploy.

Data on pipeline incidents collected by the Department of Transportation provided an additional perspective on why leak detection systems are viewed as having three components (Personnel, Procedures, and Technologies). Of 5,610 onshore spills reported as *significant* between 1993 and 2012, the main causes were corrosion (19%) and third party generated spills such as those that occur during excavation (22.5%). The primary causes of *serious* incidents occurring during this period resulted from incorrect operation (12.4%) and excavation (33.2%).

A final conclusion was that "Leak detection system complexity or high cost does not necessarily translate to better performance. Without a focus on all three: technology, people and procedures, a single "weak link" can render the overall system useless. In particular even very simple technologies can be very effective, if they are backed up by highly skilled operators and well-designed procedures.

Design choices need to be balanced with available and committed operating and maintenance resources."

It appears from the detailed discussion in the Leak Detection Study of how the oil and gas industry operates, that the appropriate focus for Odyssian might be areas of high environmental sensitivity. "Pipelines often have relatively short sections where leak detection is far more critical than in others. Examples include: river crossings (even small emissions are carried long distances); road crossings (vibration, immediate contact with moving machinery); hospitals, schools and other low-mobility areas (limited escape capability). There is a need for a certified, *dedicated point solution* that is predesigned and pre-configured for each of these common situations."

Competing Products

Competing approaches for leak detection were reviewed including: Computational Pipeline Monitoring (CPM), acoustic leak detection, remote sensing using air platforms, strain sensors, pressure and temperature sensors, Supervisory Control and Data Acquisition (SCADA) Pressure Point Analysis, and External Sensors. A summary table in the full report briefly describes how each contrasting technique works, provides illustrative names of companies that provide that approach and provide additional information that highlights the value proposition. In pursuing the Oil and Gas industry it will be important that Odyssian contrast the feature, advantages, and benefits of its technology relative to other solutions that exist. If the Odyssian system can greatly reduce false positives, this should be highlighted.

Other industries where leak detection is important

Apart from the oil and gas industry, it is reasonable to assume that leak detection in other industries is important. A quick review of leak detection in the water, wastewater, renewable and alternative energy industries was provided. In a study conducted by The Fredonia Group, it was projected that the demand for water and wastewater pipe in the U.S. is estimated to rise 5.8 percent annually to $19.6 billion in 2014. Advances will reflect renewed activity in the residential building construction sector, the growing obsolescence of sewer and drainage systems and upgrades of municipal water systems. Another study conducted by Frost and Sullivan indicated that the global leakage levels of water average 25-30 percent. In areas where water is treated as a precious commodity the interest in leak detection is highest. For example, the Las Vegas water district implemented a PermaLog remote leak detection system.

Specialty pipelines are required for renewable and alternative energy substances as their chemical composition is often corrosive or destructive to the existing, conventional pipeline infrastructure. A 2010 report prepared by SBI Energy estimates that the total global market for specialty pipelines will show year over year increases of 30% through 2015. A summary of the growth rate of pipelines needed for the transport of carbon dioxide, ethanol, biodiesel, biogas, and bio-methane are included.

Leak detection is also an issue with pipes that carry water, wastewater, and alternative fuel. However, just as with the oil and gas industry, it is suspected that there are selective areas along the distribution network where an alternative to current methods may be required. To determine the specific niche where Odyssian's technology will be valued, will require primary market research. This section of the report concludes with an illustrative approach for collecting feedback from individuals

who are responsible for leak detection in highly sensitive areas such as river crossings, road crossing, hospitals, and schools. Sample questions are included.

Seals Market

Odyssian anticipates using a licensing strategy to bring its patented products to market. Therefore, in this section insight was provided into selected players that manufacture mechanical seals. Of particular interest is EnPro Industries, a leading manufacturer of high-performance industrial seals, bearing, and compressor components. Since 2003, EnPro has made 28 acquisitions including Pipeline Seal and Insulator Inc. (PSI). " The company complements Garlock's Pikotek line of products offered to the oil & gas production market, providing it with a more comprehensive offering in this space, and 2) it represents Garlock's initial presence in water and wastewater transmission, a market that is likely to grow in the coming years due to the need to replace aging infrastructure throughout the U.S. and Europe." A summary of sealing product segment subsidiaries is included which highlights whether sales to OEMs and/or aftermarket.

Highlights from a 2010 Frost and Sullivan report on the global mechanical seals market are also included. The top three players: EagleBurgmann, FlowServe, and John Crane account for 74.8% of the global mechanical seals market.

Potential Sources of Funding

Odyssian is looking for additional sources of funding to continue the maturation of its technology. Although the technology has been tested and has performed well in laboratory environments, it needs to be tested in the field. Within the Small Business Innovation Research (SBIR) program, it was recommended that Odyssian reach out to the Department of Energy SBIR Program Manager, Manny Oliver. In addition other initiatives conducted at the National Energy Technology Laboratory (NETL) may be appropriate. Other initiatives funded through the Department of Defense, the Environmental Protection Agency, and the Department of Transportation were discussed.

4.0 SIGNIFICANT FINDINGS, PROBLEMS, TRENDS & IT'S IMPACT ON FURTHER DEVELOPMENT

The preliminary market analysis and relatively recent pipeline accidents emphasizes the need to establish continuous real time monitoring of pipeline integrity. In particular, there is a growing awareness of the hazards and environmental impacts of small leaks that are currently undetectable. Multiple technical solutions are being explored for improving leak detection, yet most are not focused on continuous real time monitoring capable of pinpointing the source of leaks or the precise location of damaging impacts. Meanwhile, information technology and the associated networking infrastructure needed for a Smart Pipeline Network continues to proliferate. The trend is that many consumer and industrial products are increasingly taking advantage of the benefits of being networkable devices. It has become evident to most consumers that significant advances are made when information and communication systems, as well as sensor-laden devices are networked using well-established Internet protocols.

While networkable smart systems continue to evolve and become evermore affordable, there appears to be reluctance by the O&G pipeline operator community to embrace smart pipeline technology that will provide significant insight into the magnitude of leaking systems. The current market dynamics appear to provide inadequate financial incentive for the pipeline operators to incur the significant cost of correcting unsatisfactory containment conditions of some of the aged pipeline infrastructure. The enforcement of federal laws and subsequent regulations may be needed to provide the incentive to adopt smart pipeline and other leak preventative technologies. The Pipeline and Hazardous Material Safety Administration (PHMSA) will most likely have to continue to be the primary source of funding to continue the advancement of smart pipeline technology until the time that regulatory consequences are high enough to provide the incentive needed.

Garlock Pipeline Technologies (GPT), who has collaborated on the development of the sensorSPACER and sensorSEAL, has expressed interest in purchasing or licensing Odyssian's related technology. The outcome of this expressed interest may depend upon the estimated time that will be required to achieve adequate market demand. This demand will depend upon how incentivized the pipeline industry becomes, as well as perception that the pipeline industry will have toward the level of technology maturation of the smart pipeline technology. Further federal funding is needed to characterize and validate the technology to the level needed to entice early adopter's.

5.0 FURTHER DEVELOPMENT NEEDED

Further development is needed to commercialize the smart pipeline technology. Specifically, the networkable components (sensorSPACER, etc.), sensors, and the overall networked cloud control require further evaluation and demonstration to characterize and validate the technology. Engineering and manufacturing development and validation is needed to demonstrate consistent product performance and to prove adequate in-field operation. Sensors need to undergo prolonged testing under environmental and operational conditions to prove adequate life-cycle performance.

Odyssian Technology's ROM estimate is that approximately $2M to $3M over 2 to 3 years is needed for adequate development, testing, and validation.

6.0 REQUIRED GOVERNMENT ASSISTANCE

Government assistance is needed to establish and enforce regulations that will incentivize the O&G pipeline industry to adopt and promote smart pipeline and related technology. Additional government funding is needed to further develop, characterize, and validate the technology. Mechanical seals are a great source of leaks and further funding is needed to develop smart mechanical seals that detect leaks and monitor performance. Small sensors that lend themselves to integration within components of the smart pipeline (i.e., smart pipe, etc.) need to be further developed, tested, and validated.

	Attachment J.1 (DEC 2010)
SUMMARY REPORT	
Topic No:	DTRT57-12-10048
Project Title:	Smart Pipeline Network – Cased Pipe for Monitoring and Sensor System
Phase II: _____ Phase II B: _____	
Firm Name	Odyssian Technology
Address:	511 East Colfax Avenue
City, State, Zip:	South Bend, Indiana 46617
To best of my knowledge and belief the data provided below is accurate, complete, and current as of the date of signature below.	

PRINCIPAL INVESTIGATOR
Name Barton Bennett
Title Co-Founder & CTO

SIGNATURE 

DATE JULY 25, 2013

Telephone No. 574-257-7555
E-mail Barton.bennett@odyssian.com

CORPORATE/BUSINESS OFFICIAL/PROJECT DIRECTOR
Name Barton Bennett
Title Co-Founder & CTO

SIGNATURE 

DATE JULY 25, 2013

Telephone No. 574-257-7555
E-mail Barton.bennett@odyssian.com

PERIOD OF PERFORMANCE: AUGUST 15, 2012 TO JULY 26, 2013

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Attachment J.1 (DEC 2010)

SUMMARY REPORT	
Topic No:	DTRT57-12-10048
Project Title:	Smart Pipeline Network – Cased Pipe for Monitoring and Sensor System
Phase II: _____ Phase II B: _____	
Firm Name	Odyssian Technology

During the program period of performance, research and development was conducted and design concepts were developed for a cased pipe spacer having integrated leak and impact detection sensors. Odyssian Technology teamed with the Pipeline Research Council International (PRCI) to provide input on the related needs of its pipeline operator membership. To assist with this process, Odyssian Technology in conjunction with PRCI leadership, established the PRCI Smart Pipeline Steering Committee that was made up of representatives from various pipeline operator companies, as well as PRCI staff members. After gaining a better understanding of current methods and construction of cased pipe, as well as the related technology interest of some of the pipeline operators, activity was directed toward developing 'open access' pipe spacer concepts instead of monolithic dual walled smart pipe concepts.

Odyssian Technology started by researching and evaluated commercially available cased pipe spacer systems. It was learned through this research that cased pipe spacers with open axial access were commercially, requiring only a modification of existing spacer systems to introduce leak and impact detection sensors. Near the beginning of the program, Odyssian Technology established a business relationship with an international provider of cased pipe spacers. This company assigned personnel to assist Odyssian Technology in evaluating their open-access spacers for use as a baseline from which to develop a smart cased pipe spacer. A metallic spacer for a 4" steel pipe was selected for use in developing a smart cased pipe spacer. Odyssian Technology developed the electronic circuitry and software to convert this selected spacer into a networkable cased pipe spacers having integrated leak and impact detection sensors.

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	Attachment J.2 JAN 2011
PHASE I COMMERCIALIZATION REPORT	
Topic No:	DTRT57-12-C-10048
Project Title:	Smart Pipeline Network – Cased Pipe for Monitoring and Sensor System
Firm Name	Odyssian Technology LLC
Address:	511 East Colfax Avenue
City, State, Zip:	South Bend, Indiana 46617
PROVIDE NARRATIVE AND RELEVANT STATISTICAL DATA.	The 2012 Leak Detection Study conducted by the PHMSA points out that 44% of these old, over 170,000 miles, hazardous liquid pipelines are in High Consequence Areas —which means that peoples' lives are at risk if they leak or spill. Thus, it is important that leak detection systems are used to promptly identify when a leak has occurred so that appropriate response can be initiated quickly. Analysis of historical incident data reported by US pipeline operators allows calculation of the financial consequences of leak scenarios. US Pipeline & Hazardous Materials Safety Administration (PHMSA) data and statistics for distribution and transmission pipelines show 730 hazardous liquid pipeline accidents between Jan. 1, 2010, and August 2012 with 241 involving at least 10 bbl. Average cost/accident was $1,343,041. Average cost/bbl released was $4,263. This analysis excludes fines, damage to the company image, imprisonment, and other consequences more difficult to quantify. Costs include: • Product loss. • Property damage and repair. • Emergency response. • Environmental damage The gas pipeline explosion December 11, 2012 in West Virginia is a classic example of the hazard of an undetected leak. This explosion demonstrates the current method of monitoring pipelines inadequate and unable to alert pipeline operators of pending danger. In this scenario the annular space of the pipe filled with natural gas and blew up under a train. http://www.npr.org/blogs/thetwo-way/2012/12/13/167169109/no-alarm-sounded-when-the-west-virginia-pipeline-exploded Odyssian Technology's Smart Pipeline Cased Pipe for Monitoring and Sensor System will offer a solution for detecting the leak before it reaches dangerous levels. The sensors cased within the spacers will not only detect pressure and gas but also movement, as in the case of an earthquake. The Cased Pipe will prove particularly important for pipes that have hazards materials such as oil, and gas as well as renewable and alternative energy substances with very corrosive and destructive chemical compositions.

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PHASE I COMMERCIALIZATION REPORT	
Topic No:	DTRT57-12-C-10048
Project Title:	Smart Pipeline Network – Cased Pipe for Monitoring and Sensor System
Firm Name	Odyssian Technology LLC
Address:	511 East Colfax Avenue

Please describe the degree of interest made by third parties, other Federal agencies, state and local governments, as well as private enterprise, in acquiring the products or services developed under this contract

Odyssian Technology anticipates using a licensing strategy to bring its patented products to market. Of particular interest is EnPro Industries, a leading manufacturer of high-performance industrial seals, bearing and compressor components. Galock's Pikotek a division of EnPro Industries has worked closely with Odyssian by providing existing technologies and substantial information of the current sealing methods including current short falls and future needs. Garlock has shown great interest in the Smart Pipeline Network Cased Pipe for Monitoring and Sensor System. Their current involvement in the pipeline sealing and spacers positions the Cased Pipe in an area of high interest in their product development. Do to this interest Garlock Seals has indicated its willingness to conduct primary market research to determine how real this opportunity is.

Please describe the potential market for the products or services developed under this contract for the purpose of applying it to other commercial markets.

Apart from the oil and gas industry, it is reasonable to assume that leak detection in other industries is important. The importance of leak detection in the water, wastewater, and renewable and alternative energy industries is a growing concern. In a study conducted by The Fredonia Group, it was projected that the demand for water and wastewater pipe in the U.S. is estimated to rise 5.8 percent annually to $19.6 billion in 2014. Advances will reflect renewed activity in the residential building construction sector, the growing obsolescence of sewer and drainage systems and upgrades of municipal water systems. Another study conducted by Frost and Sullivan indicated that the global leakage levels of water average 25-30 percent. However, just as with the oil and gas industry, it is suspected that there are selective areas along the distribution network where an alternative to current methods may be required. Additionally, in areas where water is treated as a precious commodity the interest in leak detection is highest. The Smart Pipeline Network – Cased Pipe for Monitoring and Sensor System will lend itself well in sensing movement and pressure. Humidity sensors will be used in place of gas sensors to sense water leakage and leakage levels.

Specialty pipelines are required for renewable and alternative energy substances as their chemical composition is often corrosive or destructive to the existing, conventional pipeline infrastructure. A 2010 report prepared by SBI Energy estimates that the total global market for specialty pipelines, transport of carbon dioxide, ethanol, biodiesel, biogas, and bio methane, will show year over year increases of 30% through 2015. Odyssian's Smart Pipeline Cased Pipe for Monitoring and Sensor System will readily sense and alert operators of a pending threat. The system will prevent these corrosive and destructive products harming and/or destroying life and nature.

Please describe the potential market for the products or services developed under this contract for the purpose of applying it to Government requirements.

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The existence of a market depends upon the availability of funding and the ability of a provider to address the need in a cost-effective and approved way. The 2012 Leak Detection study concluded with a discussion of operator opinions regarding budgets for leak detection systems. These discussions indicated that budgets are limited and driven be a desire to meet regulation. Technologists included in this study indicated that regulations were key to enabling their technologies to be adopted.

- "The opinion of the large majority of interviewees was that that overall leak detection budgets are driven by an honest desire to meet regulations and industry standards, but no more. In order to secure a program budget from the board, a case has to be made that it is necessary to meet an external standard or obligation.
- The interviewees [which did not include representatives from the corporate risk analysis group] did not think that leak detection was a significant consequence mitigation measure at the corporate level.
- The personnel interviewed were given working budgets for a period of between one and five years. Therefore actual investment in leak detection has to be taken out of additional departmental responsibilities (metering, SCADA, Information Technology).
- They are all regularly asked to rank potential technical options in terms of costs and benefits. Despite this, a large number reported that even very cost-effective options are often excluded if they do not follow accepted internal procedures. Following a tried and tested approach is usually valued more highly than cost-benefit.
- Those included in the study indicated that their companies carried liability insurance specifically against "pipeline losses".
- The technology developers considered that regulation alone is largely responsible for the adoption of their products, at any price."

In the Oil and Gas industry, the market opportunity for leak detection exists because of a number of federal regulations. Most recently, the Pipeline Safety Improvement Act of 2006 encouraged the continued study of pipeline safety and security practices and mandated a leak detection study. In 2007, this study was commissioned by the U.S. Department of Transportation Pipeline and Hazardous Materials Safety Administration (PHMSA) and was issued in 2012 as the Leak Detection Study. Three types of leak detection systems (LDS) were defined and categorized in this report: (1) visual inspection techniques; (2) instrumented monitoring of internal pipeline conditions; and (3) external, instrumentation for detecting leaked hydrocarbons. This comprehensive study defines a leak detection system (LDS) as having three components, all of which must be considered: Personnel, Procedures, and Technologies. According to operators, "false alarms" are a major concern and are not the result of the LDS not functioning properly. False alarms reflect the fact that normal operational changes on or near the pipeline can cause exactly the same physical effects that the LDS uses to detect leaks. "It is an inherent difficulty with any technology that relies upon any physical side effect of a leak for its detection." Another issue mentioned was that external systems are often quite complex and are difficult to select, engineer, and deploy. Leak detection system complexity or high cost does not necessarily translate to better performance. Without a focus on all three: technology, people and procedures, a single "weak link" can render the overall system useless. In particular even very

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Project Title:	Smart Pipeline Network – Cased Pipe for Monitoring and Sensor System
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simple technologies can be very effective, if they are backed up by highly skilled operators and well-designed procedures. Design choices need to be balanced with available and committed operating and maintenance resources. Odyssian's plan to install, maintain and monitor the Smart Pipeline Network System will prevent costly maintenance error, damaging leaks, loss of product, loss of life, harm to the environment and fines and/or penalties. In light of the oil and gas industries current standard practice of merely working to meet government requirements and regulations change will not occur without additional regulation. The Smart Pipeline Sensor Network System is a viable solution for leak detection suited for installation on both new and old pipelines. But just as has been seen with many other technologies and as was stated by the interviewees no change will be made within this industry without stringent requirements/regulations and shorter timelines to implement. These industries must not merely react to disasters but they must prevent them.	
Patents & Patents Applied for have has been reported in accordance with H.12.	No Patents have been filed, as of yet, that have been developed from program related technology. Previously held patents related to the Smart Pipeline Network technology as listed below. 1. Seals with Integrated Leak Progression Detection 11/090,527 Granted/Registered –United States 2. Seals with Integrated Leak Progression Detection 08 727 381.9 Examination Report - Received European Patent Office – United States 3. Gaskets and Seals with Integrated Leak Detection Capabilities PCT/US09/65695 Examination Report Received – Patent Cooperation Treaty 4. Seals with Integrated Sensor 8,601,211 Granted/Registered–United States 5. Composite Repair for Pipe and Monitoring Assembly 13/396,294 Application Filed – United States 6. Composite Repair for Pipes 8,113,242 Granted/Registered – United States
Have you issued a press release or media for publicity?	Odyssian Technology is in the process of updating its website. Upon completion press releases will be issued to Government Agencies PHMSA, DOE, NETL, DOD, EPA, AND DOT Oil and Gas Pipeline Water Industry operators and specialist City Municipalities

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Attachment J.3 (April 2010)

SBIR Phase I
CONTRACTOR REPORT OF GOVERNMENT PROPERTY

1. Contract Number: DTRT57-12-10048

2. Report Period Ending: July 25, 2013

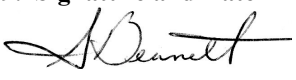
3. Contractor (Name and Address)	**4. Contracting Office (Name and Address)**
Odyssian Technology 511 East Colfax Avenue South Bend, Indiana 46617	USDOT/RITA/Volpe Center Contracts & Tech support Services 55 Broadway RVP-32 Cambridge, MA 02142-1001

5. Name and location of Government-Owned, Contractor-Operated Plant (if applicable)
NONE

6. Any Government property located at a subcontractor's plant? _____ Yes X No. If yes, give the name and address of the subcontractor(s) on an attached sheet to this report.

7. Property Class (See FAR 45.5)	Item/ Description	Unit Price In dollars	Quantity	Total Acquisition Cost	Invoice Date	Required for Phase II.B or Phase III (yes/no)
Plant Equipment						
Special Test Equipment						
Special Tooling						
Materials in Stock						
Other Real Property						

NOTE: This report shall include all Government property (i.e., property furnished by the Government, or acquired or fabricated by the contractor or subcontractors). By signature hereon, the contractor's property administrator declares that the report was prepared from the contractor's records.

8. Typed Name of Contractor Property Administrator	**9. Signature and Date**
Susan Bennett	

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DOT SBIR Phase I
Contract No: DTRT57-12-C-10048
DTRT57-12-C-10049
DTRT57-12-C-10050

Assertion of Data Rights

Required Data Rights Assertion FAR 52.227-20

Technical Data to be Furnished With Restrictions*	Basis for Assertion**	Asserted Rights Category***	Name of Entity Asserting Restrictions****
Concepts, technology, and data related to multifunctional or smart seals, smart gaskets, rubber sealing sensors and custom pressure sensors.	Developed under non-federal funds	Limited Rights	Odyssian Technology
Concepts, technology, and data related to hydrocarbon sensing.	Developed under non-federal funds	Limited Rights	Odyssian Technology
Concepts, technology, and data related to sensors to detect leaks in water distribution, gasoline piping and storage tanks.	Developed under non-federal funds	Limited Rights	Odyssian Technology
Concepts, technology, and data related to multifunctional sandwich electronic structures including dual wall truss electronic piping.	Developed under non-federal funds	Limited Rights	Odyssian Technology
Concepts, technology, and data related to smart collar (sensor boot).	Developed under non-federal funds	Limited Rights	Odyssian Technology