Exhibit A
SCOPE OF WORK
Natural Gas Pipeline Sensors

TECHNICAL TASKS

Task 2 Benchmark Existing Diagnostic Approaches

The goal of this task is to benchmark existing diagnostic approaches to measuring pressure, detecting welding defects, and detecting water accumulation and corrosion in natural gas pipelines. Commercial off-the-shelf products will be used for the benchmarking. The research team will solicit assistance from local gas utilities for either the use of loaned equipment or access to installed equipment. If required, equipment shall be either leased or purchased.

A set of benchmarking metrics shall be developed and existing equipment shall be benchmarked against those metrics. The same metrics shall be used to benchmark new sensors being developed by this project. The "before" and the "after" benchmarks can be used to compare performance of the new sensors with that of existing technology.

The Contractor shall:

- Solicit assistance from local gas utilities for access to existing pipeline diagnostic equipment.
- Develop a set of parameters that will be used to benchmark existing pipeline diagnostic equipment.
- Test, evaluate, and benchmark existing pipeline diagnostic equipment.
- Prepare a benchmarking report.

Deliverables:

- Benchmarking report. (no draft)

Task 3 Design Gas Pipeline Sensors

The goal of this task is to design three next generation gas pipeline sensors:

- Gas pressure sensor that monitors the pipeline for over-pressure conditions.
- Laser-based sensor to detect defects in pipeline welds from the inside.
- Water accumulation and corrosion sensor.

Gas pressure sensor. The gas pressure sensor is a small MEMS (Micro-Electro-Mechanical System) platform – about the size of today's USB memory sticks - that would be installed in numerous locations on the inside-wall of a pipe. The package

contains a MEMS pressure sensor that has been successfully manufactured in recent years and in volume, costing only a few dollars. The package also contains a communicating radio chip (or mote). This small radio sends the pressure reading to a remote receiving station. The MEMS sensor and radio will be powered by RF (radio-frequency) energy sent from the base-station, and a local rechargeable battery will provide local storage-power. Experiments (field testing) will determine the practical specification for spacing between the MEMS platforms and the reader; and the optimal spacing between each sensor to ensure accurate pressure readings at regions over the whole pipe.

Weld defect sensor. This sensor will employ a technique to generate ultrasonic waves on the inside surface of the pipe by bombarding the surface with a modulated laser beam. The ultrasonic waves propagate into the pipe material and reflect back at discontinuities such as voids and defects, and at the outside of the pipe. A second laser beam detects induced surface motion from reflected waves. A computer system produces and displays surface and internal contours, and properties of the pipe being inspected. The system would be used inside pressurized gas pipelines, moving along the inside of the pipe (as a "crawler") to inspect welds in the pipe wall.

Water accumulation and corrosion sensor. This sensor has different characteristics depending on the materials used in its construction. As a water accumulation sensor, it is built with layers of Aluminum Oxide Platinum. A sensor to detect possible corrosion development is built with layers of Aluminum Oxide Iron. For detecting water accumulation, the sensor will be installed permanently at strategic low points in the pipeline. Using multiple stacked layers of Aluminum Oxide Platinum, the output of the sensor can indicate the level of water accumulation. For detecting possible corrosion buildup, sensors will be installed permanently and randomly along the length of the pipeline. The output of the sensor can indicate the magnitude of corrosion. Although this sensor does not detect actual corrosion in the pipe material, it will detect corrosion build-up resulting from the presence of moisture. Both sensor types will have a communicating radio chip for transmitting readings.

The Contractor shall:

- Design three types of sensor packages; gas pressure, weld defect, and water accumulation and corrosion.
- Prepare specifications, schematics, and design drawings.
- Prepare a design report.

Deliverables:

- Design report. (no draft)

Task 4 Fabricate and Demonstrate Gas Pipeline Sensor Prototypes

The goal of this task is to fabricate and demonstrate prototypes of the sensors designed in Task 3. A family of sensor packages will be fabricated using the MEMS-prototyping, rapid-prototyping, and manufacturing equipment available in the research team's facilities. These packaged sensor systems will be able to communicate in a sensor-net with each other and with the outside world. The sensor-net will also be integrated into a 3D Geographic Information System (GIS) framework. A GIS framework will allow data visualization with highly interactive user interface and integration to physical infrastructure data models with financial and condition information. The 3D-GIS database will support condition-based-monitoring and decision-making for the oversight of the natural gas lines. The completed integrated prototypes will be demonstrated to the Commission Contract Manager and other interested parties determined by the Commission Contract Manager.

The Contractor shall:

- Fabricate prototypes of the three sensor types using the designs developed in Task 5.
- Integrate the sensors with an appropriate 3D GIS framework.
- Develop database to support condition-based-monitoring and decision-making
- Make videos of the working prototypes.
- Organize and conduct a workshop to demonstrate the prototypes to the Commission Contract Manager and other interested parties as appropriate.
- Prepare presentation materials for the demonstration workshop.

Deliverables:

- Workshop presentation materials. (no draft)

Task 5 Lab Test Gas Pipeline Sensor Prototypes

The goal of this task is to lab test the prototype sensors. The lab testing will be an opportunity to do fine tuning of the operational characteristics of the prototype sensors such as calibrations and best distance for communications between adjacent sensor packages, as well as to establish baseline performance metrics.

The Contractor shall:

- Lab test the sensor prototypes.
- Determine operational characteristics such as calibrations and optimal communications distances.
- Establish baseline performance metrics.
- Prepare lab test report.

Deliverables:

- Lab test report. (no draft)

Task 6 Field Test Gas Pipeline Sensor Prototypes

The goal of this task is to field test the prototype sensors. Field testing will be coordinated with a collaborating local gas utility. The location of testing can either be in an actual operating pipeline or in a utility test facility with test pipelines that can operate with real operational parameters. Field testing will last between 2-3 months. Data will be collected for analysis in Task 7.

The Contractor shall:

- Coordinate with collaborating local gas utility access to either operational gas pipeline or gas pipeline in a test facility.
- Conduct field test for 2-3 months.
- Collect measurement data from the field test.
- Prepare report on field test.

Deliverables:

- Field test report. (no draft)

Task 7 Analyze Data from Field Test

The goal of this task is to analyze the data collected in the field test (Task 6). For each of the sensor types, the analysis will include but not limited to:

- Sensitivity of the sensors relative to the operational parameters of the pipeline.
- Accuracy and reliability of the sensors.
- Performance of the sensors as compared to existing technologies using the benchmark parameters established in Task 2.

The Contractor shall:

- Analyze data collected from the field test in Task 6.
- Determine parameters such sensitivity, accuracy, and reliability.
- Determine performance as compared to existing technologies using benchmark parameters developed in Task 2.
- Prepare data analysis report.

Deliverables:

- Data analysis report. (no draft)