# R&D and Innovation for PG&E Gas Operations

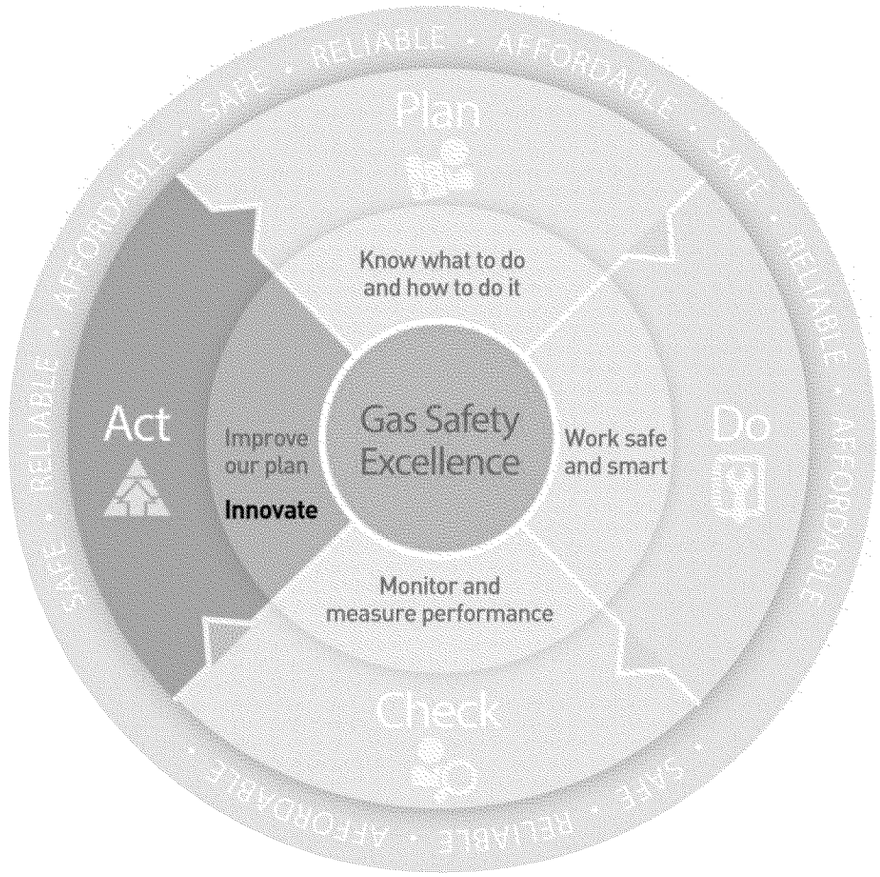
Redacted

NARUC February 9th, 2014

# R&D and Innovation part of Gas Safety Excellence

- Jeff Wiese recently pointed out the importance of R&D and Innovation to improve the safety of Transmission and Distribution infrastructure cost effectively[1]

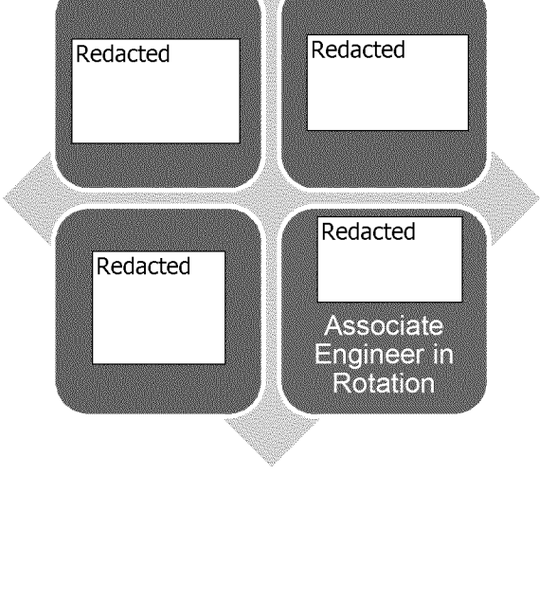
- PG&E is introducing a systematic risk based management of its assets following the continuous improvement Plan, Do, Check, Act sequence.
- R&D and Innovation is part of the Act step.

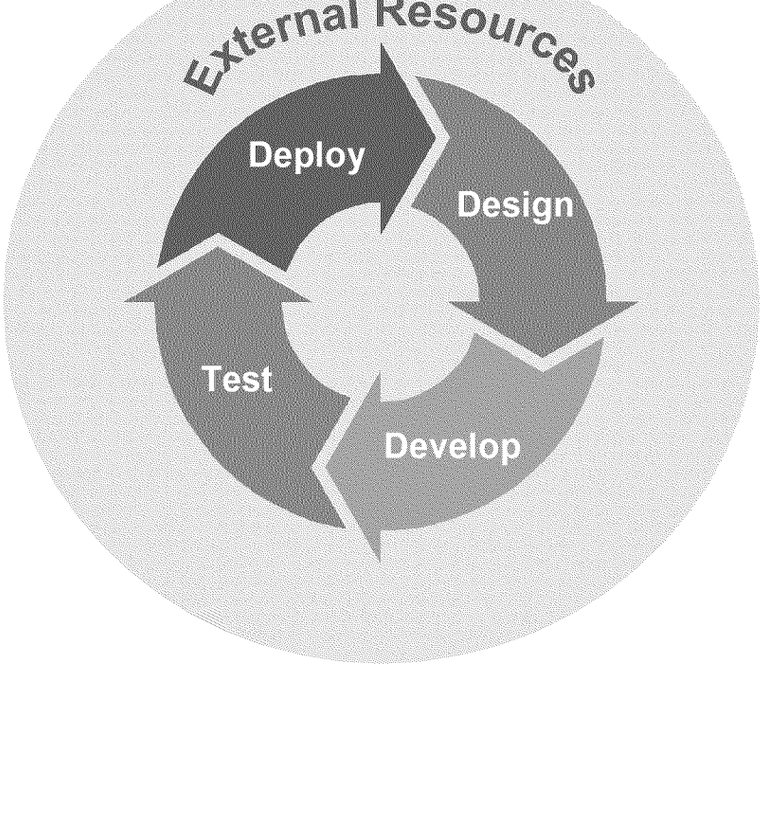



[1]: Letter to the Chairman of NARUC on April 30th, 2013

## Mission Statement

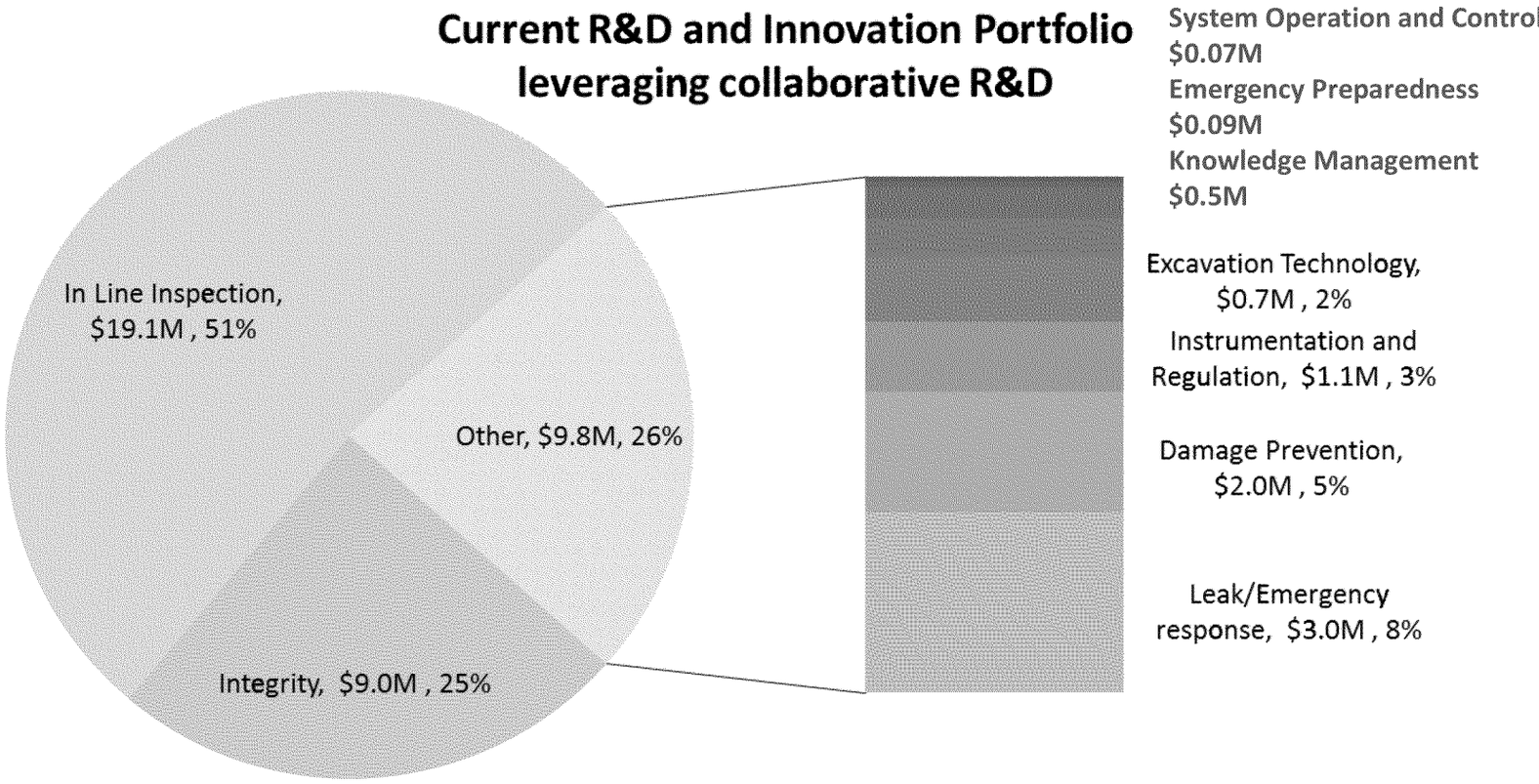
**R&D and Innovation** detects, adapts, qualifies and implements innovative solutions in the Gas Operations business to improve its performance measured in public and work safety, customer satisfaction, cost effectiveness, environmental impact, regulatory compliance, and communication.



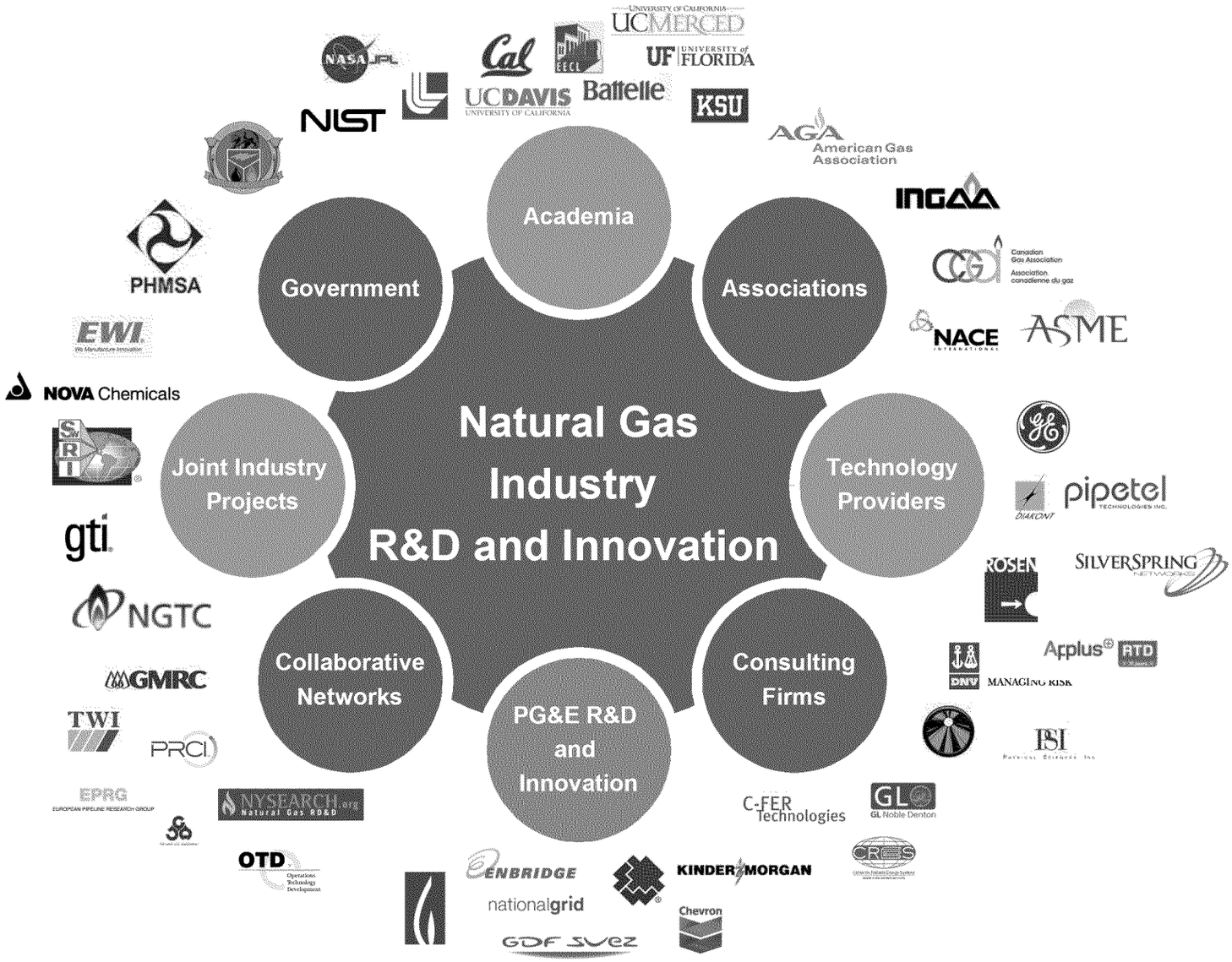
# R&D and Innovation Portfolio

- 91 active projects, 23 in evaluation (as of December 31st, 2013)




**TOTAL: $38M for $4.2M PG&E funding**

# R&D and Innovation Connection



# In Line Inspection

# Explorer 30-36” Development and First Field Demonstration

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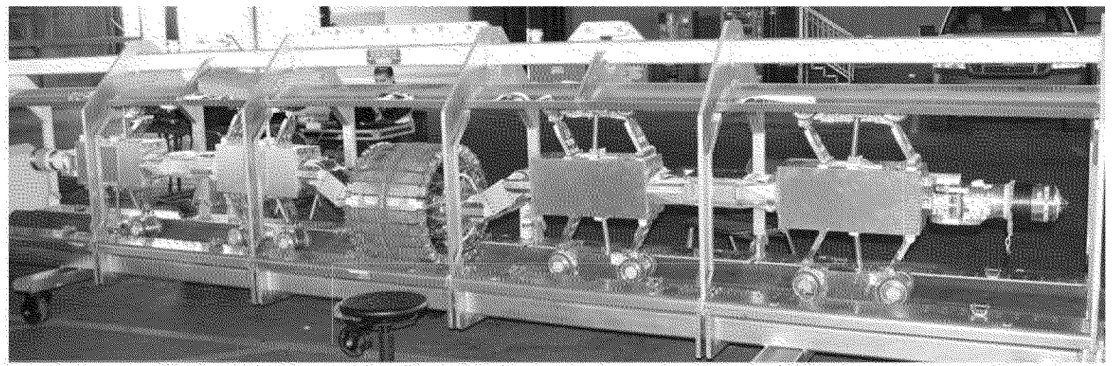
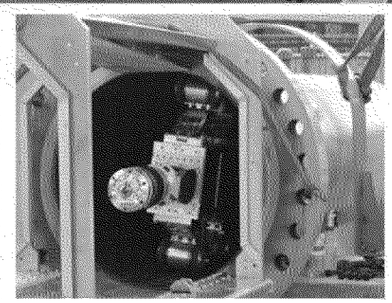
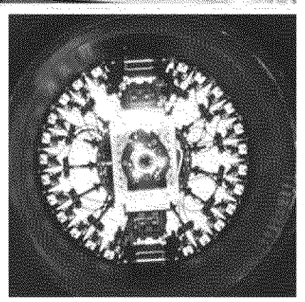




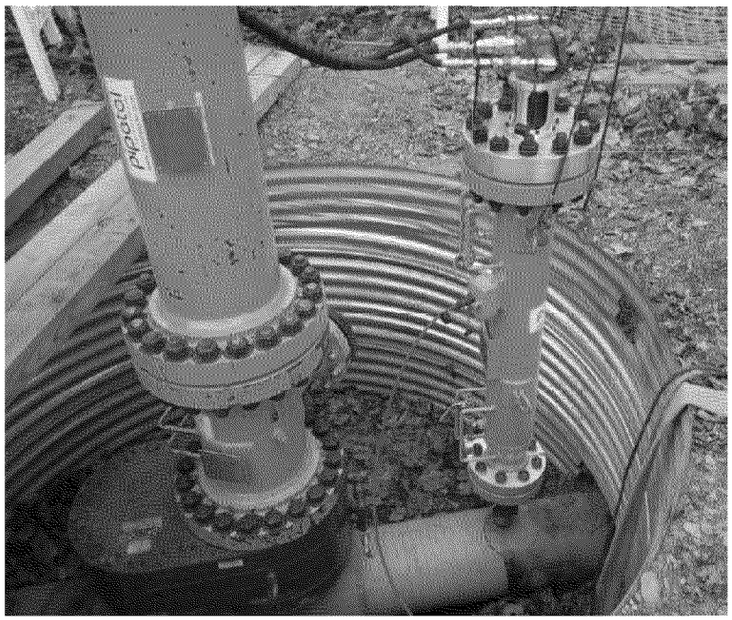


- Partnership with NYSEARCH on developing an untethered inspection robot for unpiggable 30-36” diameter transmission pipelines
- Successful demonstration performed on July 22-23, 2013 consisting of a 800 ft test run through an actual 30” live pipeline (L-153) pressurized at 320 psig.
- Next steps: 2nd demonstration at National Grid through a hot tap before commercialization in 2014.

2011 — 2014

Design | Develop | Test | Deploy

# Explorer: In-Line Charging Tool



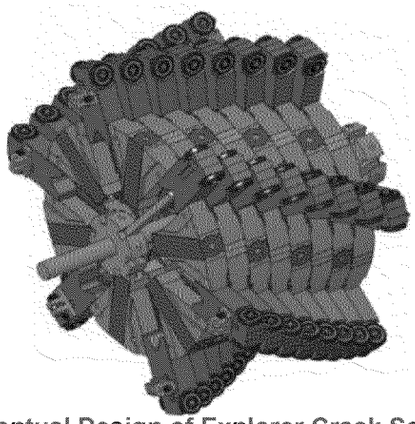
- Tool used for charging the batteries of Explorer robotic tools through a hot tap.
- Eliminates costly removal of the robot to charge the batteries.
- Two versions developed: generator and battery powered charger.
- In-line charging tool has been deployed and used commercially (Explorer 10/14 was charged multiple times to inspect 2.7 miles of a 10” and 12” diameter pipeline).

2011 2013

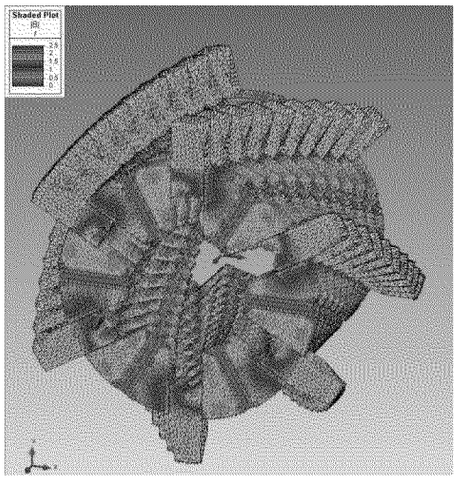
Design | Develop | Test | Deploy

Completed

# Explorer – Crack Sensor

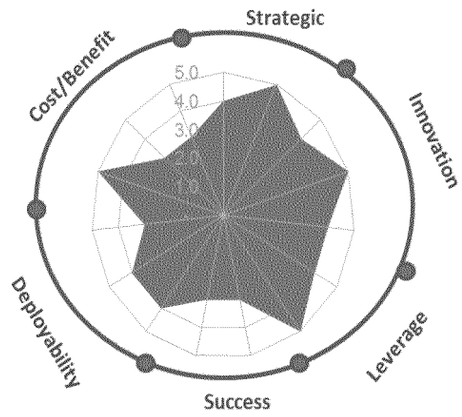


Conceptual Design of Explorer Crack Sensor




Magnetic field generated by spiral TMFL sensor

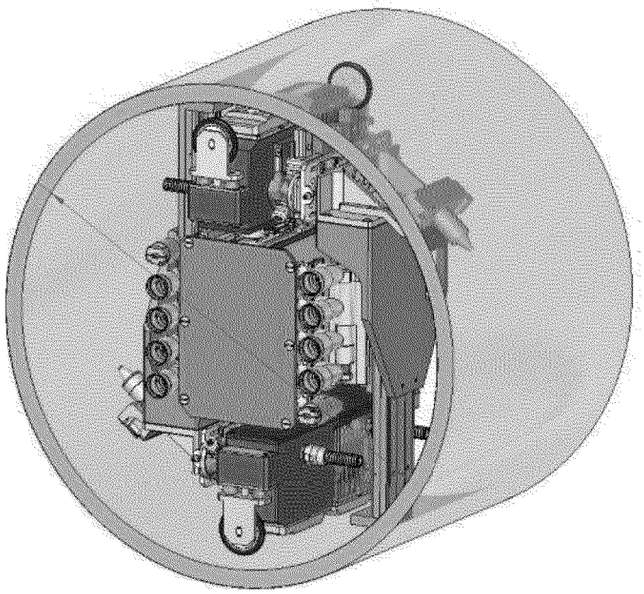
- Development of sensors for the detection of axially oriented cracks, primarily in the long seam weld.
- The design incorporates Electromagnetic Acoustic Transducer (EMAT), and Transverse Magnetic Flux Leakage (TMFL) sensors in a spiral configuration.
- Initial development will be on the Explorer 20/26 platform. Tool is expected to be completed by 1Q 2015.




2011 — 2015

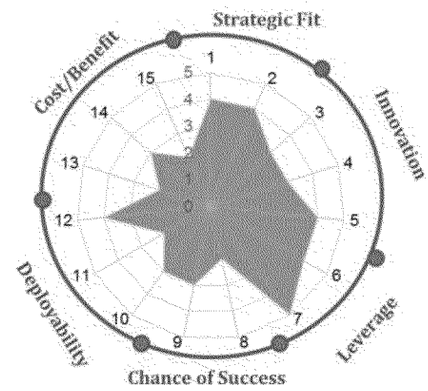
Design | Develop | Test | Deploy

# Diakont Multiple Channel EMAT



Rendering of Multi-Channel EMAT on Diakont's RODIS Crawler

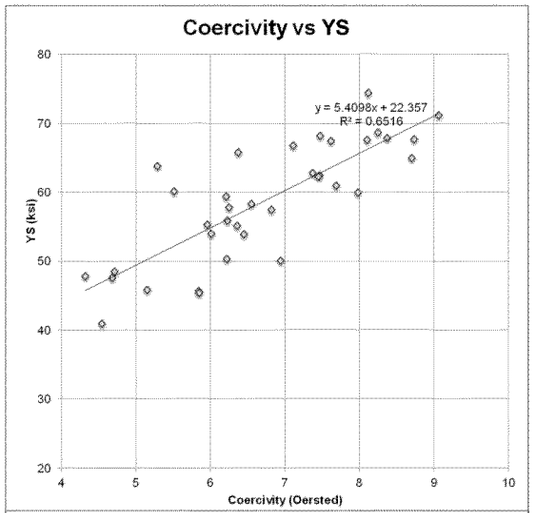
- Multi-channel EMAT sensor to allow inspection, characterization, and measurement of girth welds.
- Sensor integrated onto Diakont's tethered crawler to inspect 30"-56" diameter pipelines.
- Demonstration of test unit in PG&E territory in 2Q 2014
- Commercial availability in ~ 3Q 2014.
- Result will help:
  - Assess girth weld integrity for construction defects especially in condition of underground movements
  - Replace UT based techniques that require water coupling

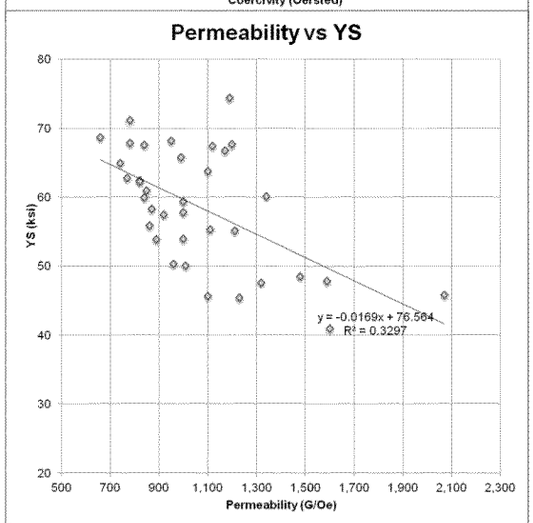



2010 — 2014

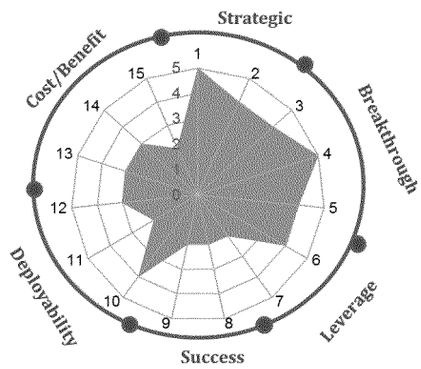
Design | Develop | Test | Deploy

# Material Characterization



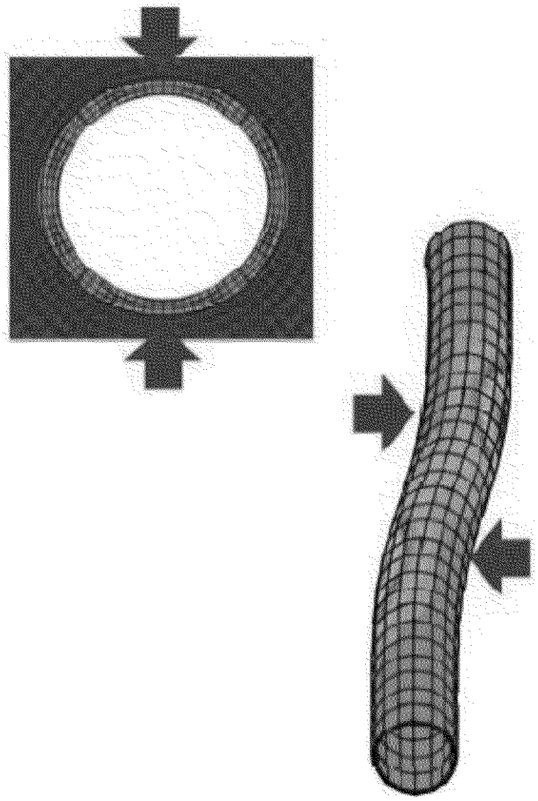

- Co-funded with PHMSA, to improve knowledge about buried pipelines through In Line Inspection and to complement PRCI project NDE-4A.
- Pipeline microstructural parameters of interest:
  - Yield strength
  - Tensile strength
  - Transition temperature
  - Fracture toughness
- Some proposed techniques to be investigated:
  - Ultrasonic backscatter testing to determine grain size
  - Other electromagnetic measurement techniques (Eddy Current, Barkhausen, etc.)
  - Additional data could determine chemical composition using x-ray backscatter methods




2013 — 2016

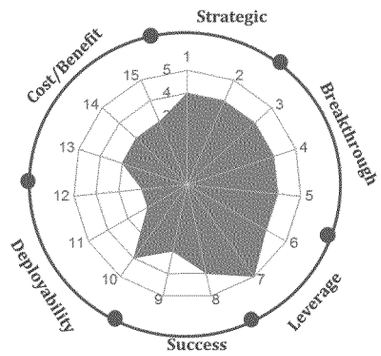
Design | Develop | Test | Deploy

# Improving MFL Storage Well Casing Assessments



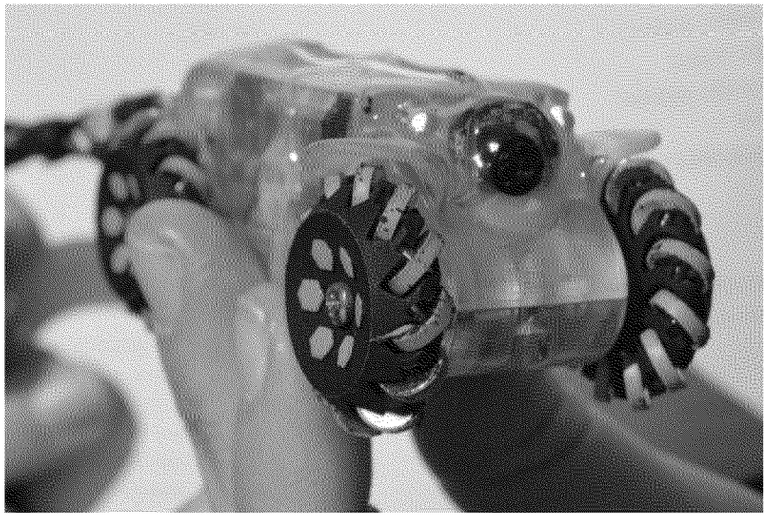
Example of Geo-mechanical Loads on Downhole Pipe

- Mechanical stresses on downhole piping due to subsidence, angle of inclination, and degree of centralization in the wellbore are investigated.
- Downhole conditions are different than regular horizontal pipeline conditions, warranting the need to characterize their effect on MFL performance and data interpretation.
- Results will help in:
  - Increasing the effectiveness of storage field Integrity Management program
  - Improving knowledge to support plug and abandonment decisions
  - Increasing service factor on storage assets through improved confirmation of remaining strength of casing



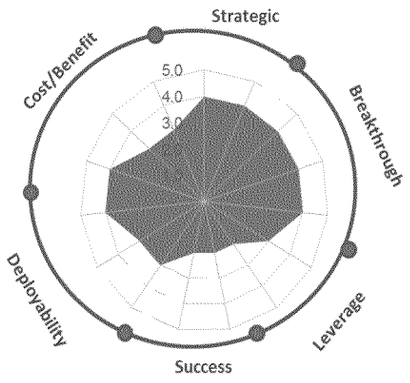

2013 Design → Develop → Test → 2016 Deploy

# Robot for Visual Inspection of Pipe Casing through Vents



Prototype of Robot for Visual Inspection of Pipe Casing through Vents

- NYSEARCH project with Honeybee Robotics initiated in 2012
- Quick visual inspection of pipe casing without digging
- Prioritization of ILI inspection and digs
- First functional prototype tested by National Grid in February 2013
- Development of a refined prototype to be tested in May 2014




2012 2014

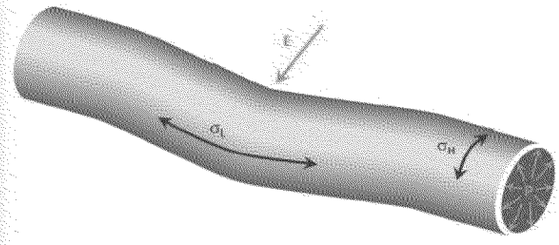
Design → Develop → Test → Deploy

# Integrity Management

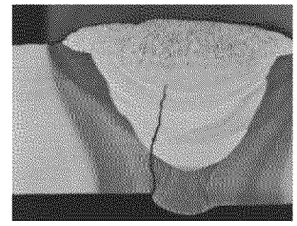
# Joint Industry Project on Ground Movements

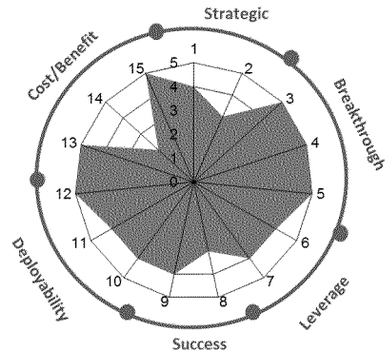
- Industry project started in April 2012 focused on development of Fitness for Service (FFS) assessments and best practice document for management of ground movement hazards
- Consortium of several oil and gas pipeline operators
- Study led by Center for Reliable Energy Systems (CRES)
  - Girth weld failures on vintage pipelines
  - Additional stresses exerted on pipelines (ground movement, residual stresses, construction activities, soil creep, heavy rainfall, etc.)
  - Characterization of pre-existing flaws on girth welds from welding (lack of penetration, hydrogen embrittlement, high-low misalignment, cracking, etc.)

Pipe Movement
→ Strain (ε) & Stress ($\sigma_L$)




Bending Strain & Stress
+
Girth Weld Features
!

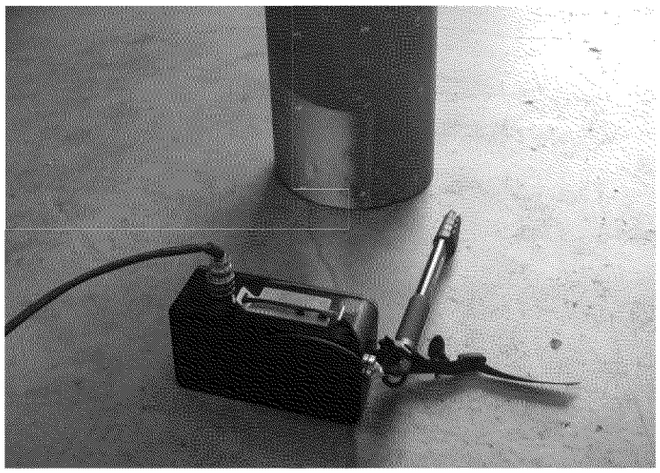


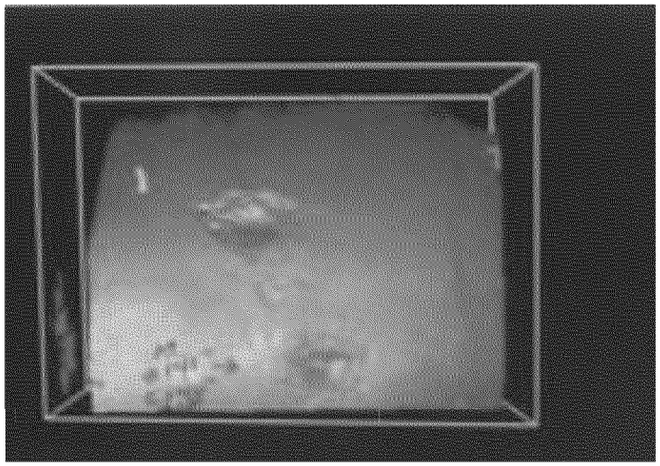



2012 — 2014

Design | Develop | Test | Deploy

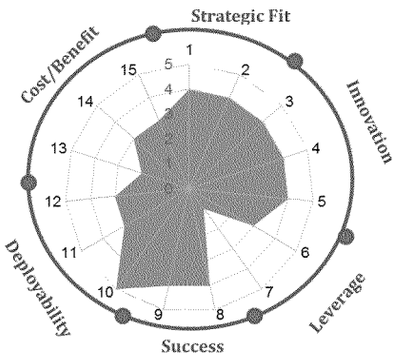
# Stereoscopic Camera to capture 3-D Images of Features





Demonstration of the Seikowave system at ATS on April 18th, 2013

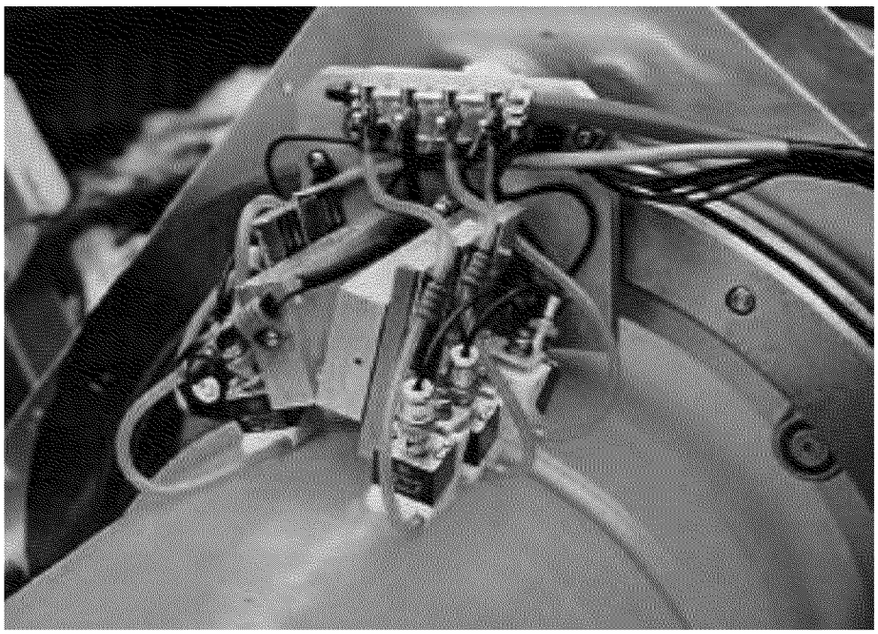
- PRCI detected the technology through the NASA Tecfusion program
- Spin-off of University of Kentucky
- Projector and receiver integrated in the camera
- Projects about 600 frames on the object to measure the volume in one picture
- Automatically creates data for calculations of RSTRENG per ASME B31G
- Analysis is provided in real time with minimal skills required from the operator.




2012 — 2014

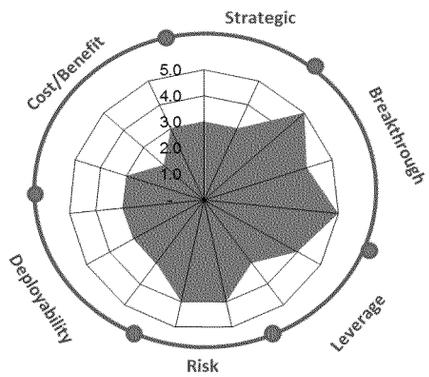
Design | Develop | Test | Deploy

# NDE for Polyethylene Butt Fusion Joints



Prototype of NDE system for Butt Fusion joints in PE pipes
**(Ref.: TWI WINDEPP Program)**

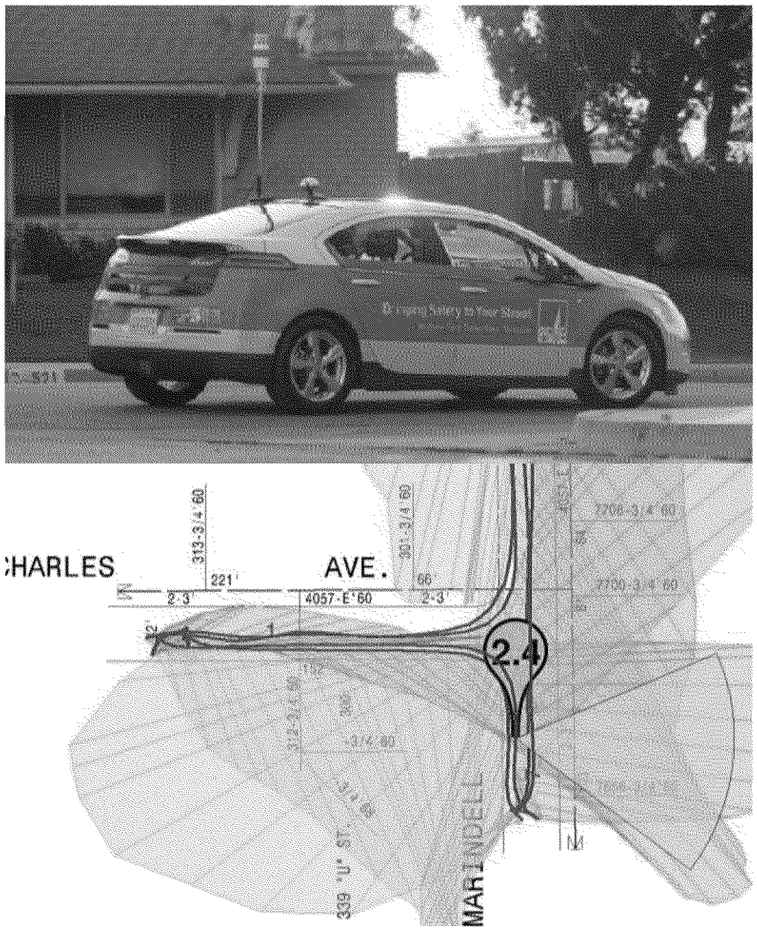
- NYSEARCH project on developing automated NDE (Phased Array UT) system for inspection of butt fusion joints of polyethylene distribution pipelines
- Current validation method is visual inspection
- Automated NDE tool increases reliability
- Will be used for Integrity Management, Training, and Quality Control




2010 — Design | Develop | Test | 2014 — Deploy

# Leak Detection

# High Sensitivity Methane Detector




- Cavity Ring Down Spectroscopy (CRDS) detects methane concentrations as low as 1ppb.
- Allows a more effective sweep of an area with a vehicle to identify possible leaks.
- Data are transmitted immediately and can be viewed remotely in real time.
- Offers many opportunities to improve leak detection process.

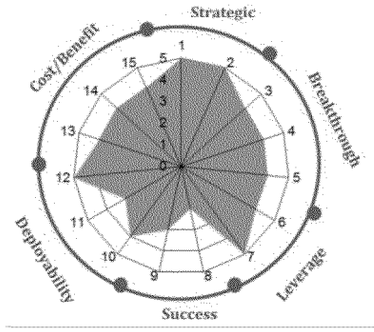
2012 2014

Design | Develop | Test | Deploy

# Light Weight Methane Detector to rapidly Locate Leaks

Prototype of Methane Detector by JPL (March 2013)

- Jet Propulsion Laboratory of NASA in Pasadena has developed a miniaturized methane detector to locate methane sources on Mars
- Precision of 10 ppb with an open path of 20 cm by using 3.3 µm absorption band.
- Allows to go from Picarro methane indication to leak by tracking the plume.
- Can be mounted on a UAV for rough terrain pipeline survey
- Partnership with PRCI and JPL to complete development and adaptation to our needs




2013 ▼ 2015

Design | Develop | Test | Deploy

# Stationary Methane Laser Sensor

Installed Remote Methane Leak Detector at PG&E Livermore Training Center (February 2013)

- Continuously monitors pipelines and provides rapid warning of leaks.
- System consists of sensor, weather station, camera and computer station.
- Testing of the system co-funded with the California Energy Commission:
  - Demonstration of sensor efficacy
  - Evaluation of sensor response to leaks in typical operating scenarios and weather conditions
  - Elimination of false alarms
- Project is completed. Results will be presented at the 2014 AGA Spring Conference.

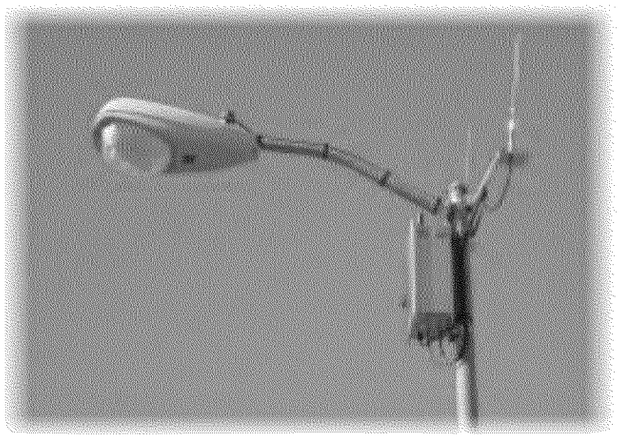
2013 2014

Design | Develop | Test | Deploy

Completed

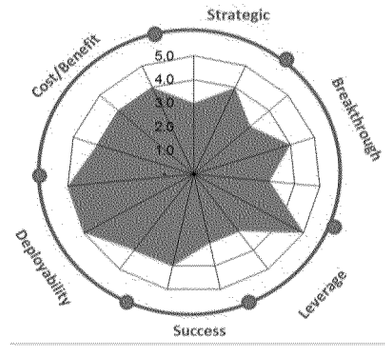
# System Operation and Control

# Using Smart Meter Infrastructure to transport Monitoring Data




ERX Unit and Data Collector Unit

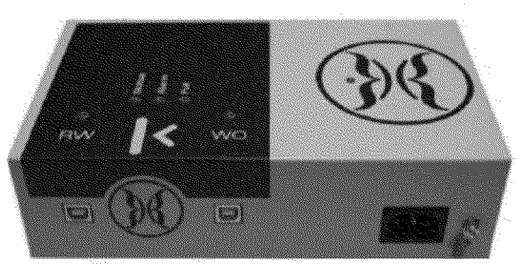
- Cost effective alternative to cellular service or dedicated wireless network.
- Demonstrated that in adequate locations, latency is shorter than few seconds.
- Installed Silverspring Networks modem on ERX to collect and transport local pressure information towards the Control Room.
- Field test completion expected in Q2 2014.

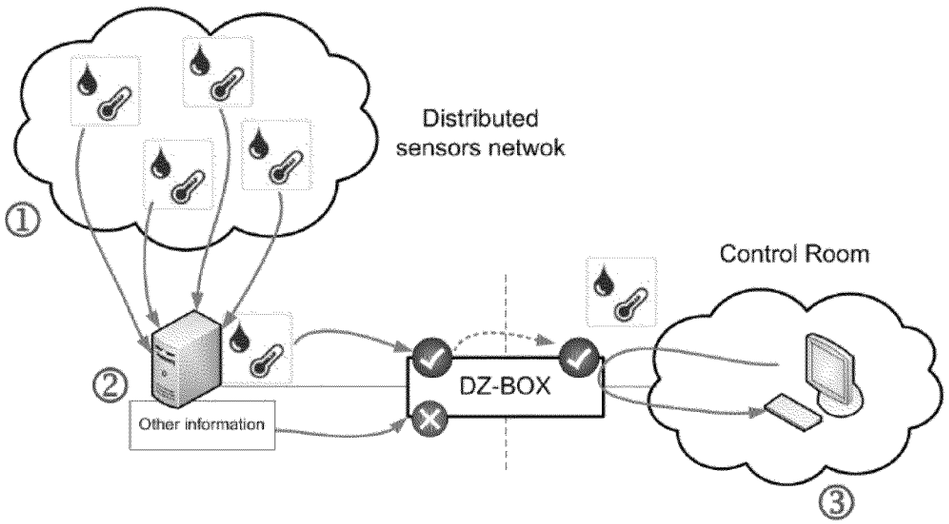



2012 2014

Design | Develop | Test | Deploy

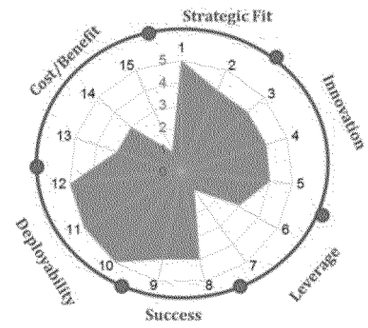
# Separating our Control Room from Public Networks






ERX Unit and Data Collector Unit

- Assures physical separation of the control room from external networks
- Controls and authorizes transfer of information from external networks to the control room
- Hardware-based solution (“security in silicon”), not subject to software flaws and configuration errors.
- Does not require any administration.




2013 ▼ 2014

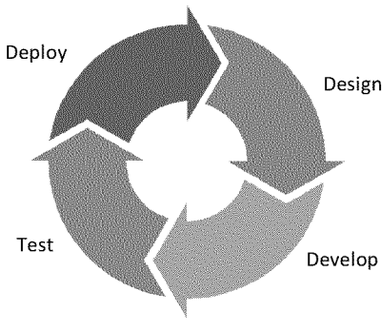
Design | Develop | Test | Deploy

# Damage Prevention

# Road Maps

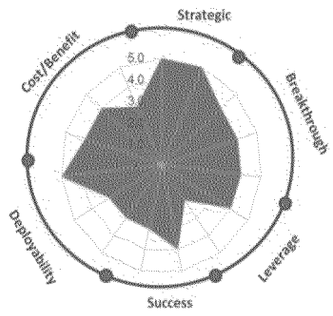
| Objectives | Needs and Gaps | R&D Projects and Technologies |
|---|---|---|
| Damage Prevention | Time line | <2012 \| 2012 \| 2013 \| 2014 \| 2015 \| >2015 |
| Prevent 3rd Party Damage | Detect Construction Equipment/Activity | Satellite Observation (PRCI) |
| | | ● Aerial Surveys - Drones (PRCI) |
| | | ● Image Analysis (PRCI) |
| | | Optic Fiber (Cost Reduction) (NYSEARCH) |
| | | ● Ground Acoustic Sensors (NYSEARCH) |
| | | Signal Analysis |
| | | Video Surveillance (NYSEARCH, PRCI) |
| | Eliminate False Alarms | ● Electronic Fence |
| | | Multiple Signal Analysis |
| | Locate Construction Equipment | ● GPS Localization (OTD) |
| | Control HDD | ● Best Practices (PRCI) |
| | | Ground Penetrating Radar (OTD, NYSEARCH) |
| | | XYZ localization sensor |
| | Locate Pipelines | ● GIS location validation (OTD) |
| | | Pipeline ROW markers |
| | Improve Communication | Smart Phone Solutions |
| | | Standardization |

● PG&E participating



# GPS based Damage Prevention

- Supplements 811 calls to provide additional protection
- Uses GPS location of construction equipment and movement patterns
- Sends alerts to field operators, and utility control room when equipment digs close to underground assets
- Built upon development made by GTI with Virginia Utility Protection Services
- Solution expected to be cheaper and more effective than ultra-sonic and fiber optic detection systems

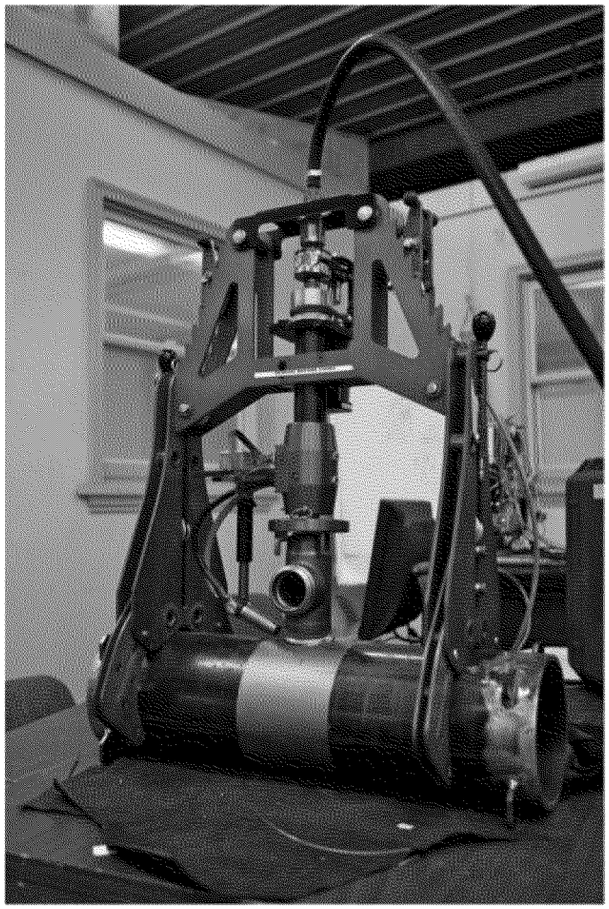



2013 2014

Design | Develop | Test | Deploy

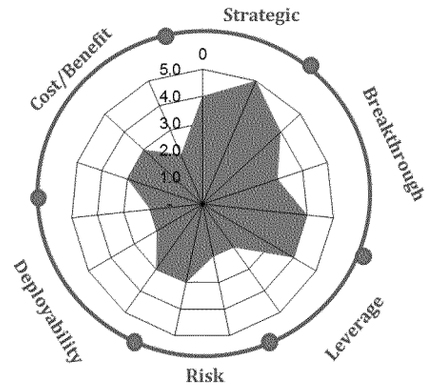
# Excavation and Construction Technologies

# Automated Welder for Laterals



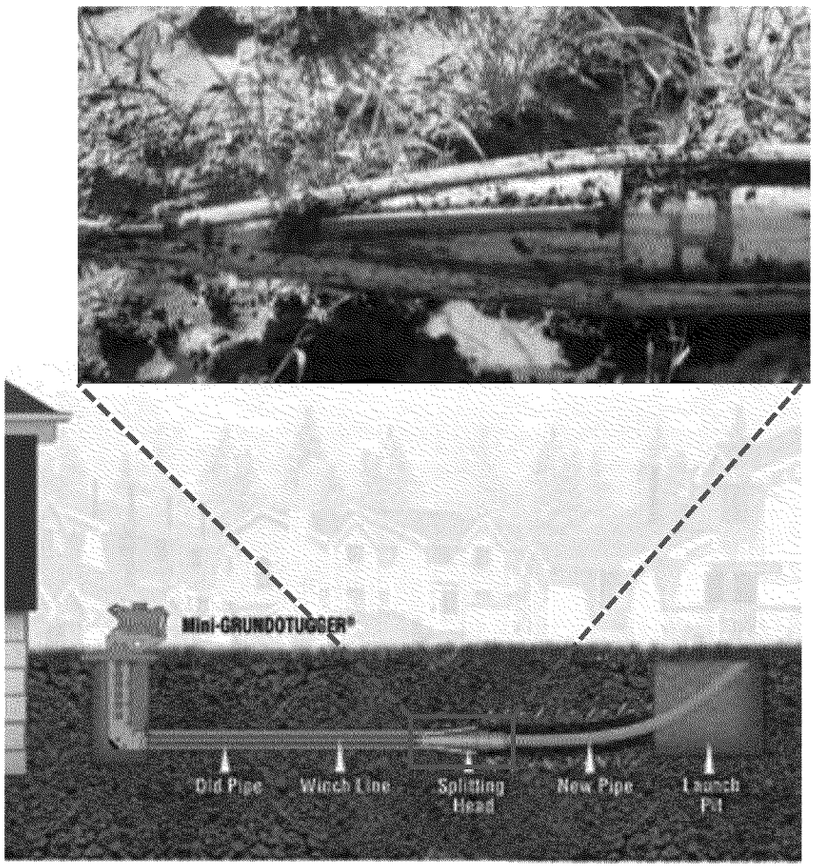
Prototype of Automated Welding Unit
(Ref: GTI, Dennis Jarnecke)

- GTI project for the development of an automated welding unit dedicated to the installation of service laterals
- Will focus on the industrialization of the prototype developed in earlier phase.
- Automated welding:
  - Improves weld integrity and repeatability
  - Reduces dependency on highly experienced welders, who are short in supply
  - Promotes safer operation by removing operator from the excavation during the operation



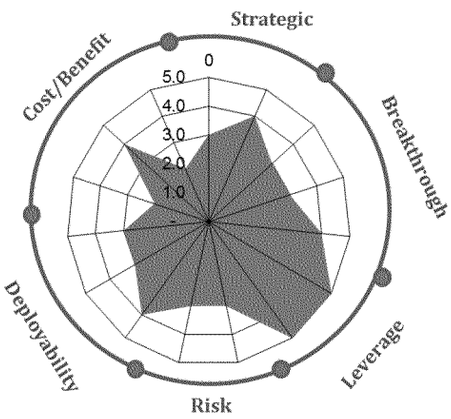

2010 — Design | Develop | Test | 2015 — Deploy

# Polyethylene Pipe Splitting Tool Development



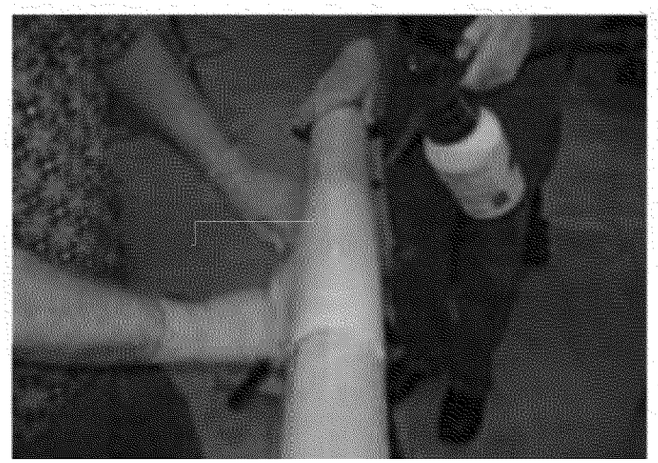

*Mini-GRUNDOTUGGER from TT Technologies*

- Pipe splitting technique involves splitting vintage Aldyl-A pipe and inserting new PE pipe in existing path
- Methodology is “trenchless” and lower in cost compared to excavation
- The project will focus on the development of standard pipe splitting tools and procedures.
- Project completion by 1Q 2015.

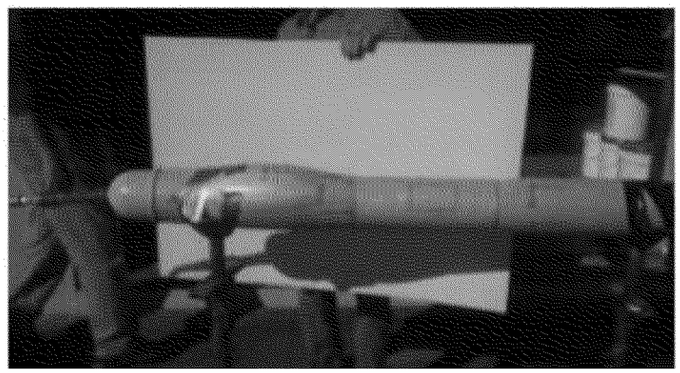



2012 — Design | Develop | Test | 2015 — Deploy

# Composite Repair on Polyethylene Pipe

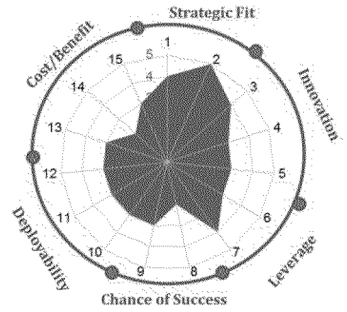


*Composite repair trial on polyethylene pipe.*



*Hydrostatic pressure test on repaired sample; failure outside of repair area.*

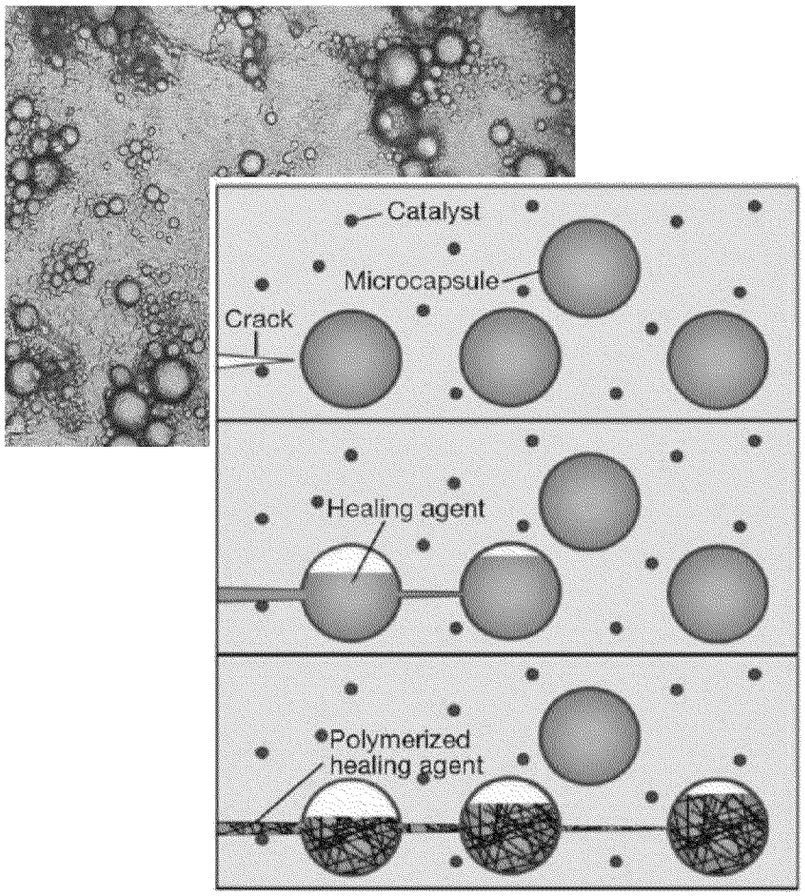
- OTD-led project to evaluate composite repair for mechanically damaged polyethylene pipes.
- Currently, damaged pipes require gas shutoff, bypass of the damaged area, cut-out, and replacement. This solution will allow for repairs of small leaks without shutting off service.
- Testing will include mechanical property testing of Pipe Wrap, lap shear strength with polyethylene, and sample repair testing including burst testing, hydrostatic pressure testing, and impact testing.
- Study is expected to be completed by 3Q 2015




2013 — 2015

Design → Develop → Test → Deploy

# Self-Healing Material and Pipe Development




Microencapsulated Self-Healing Concept
(Ref: Applied Nanotech, Dr. D. Mao)

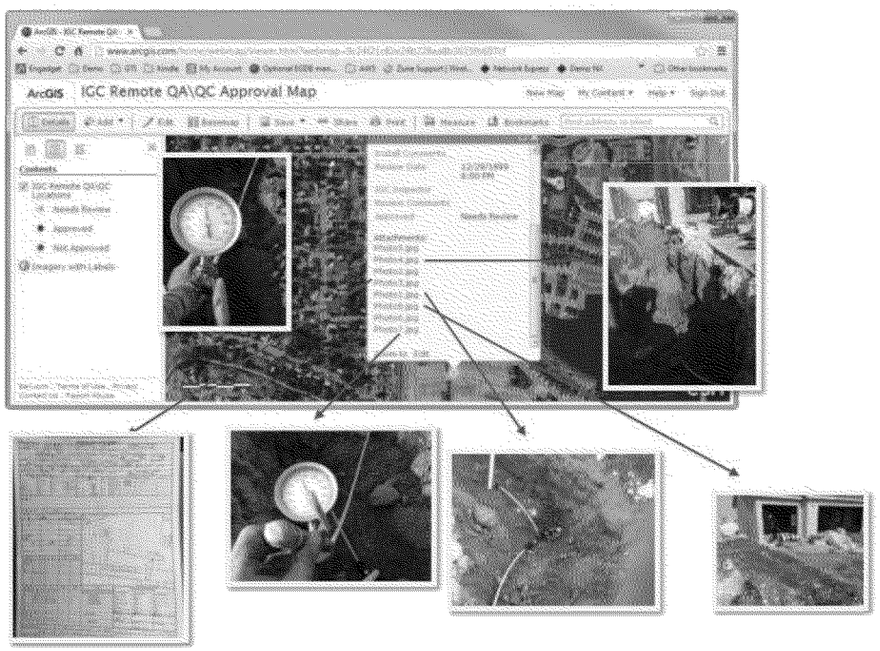
- First academic research results in 1996 for polymer matrix of composite materials
- Microcapsules containing self-healing agent embedded into PE matrix
- Cracks rupture microcapsules, activating healing agent, which prohibits further crack propagation.
- Current work is focused on proof of concept on polyethylene material
- Next step will be demonstration of extrusion manufacturing to form pipes

2012 2020

Design | Develop | Test | Deploy

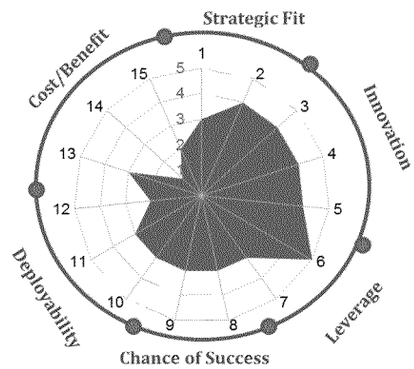
In Evaluation

# Remote QA/QC Process




*Examples of Information captured in the field and automatically loaded within the GIS.*

- Development of a remote QA/QC application to monitor the quality of field work in real-time by capturing pictures along the process.
- Remote monitoring of operations will effectively increase quality control of work by ensuring proper photo-documentation.
- Three pilot projects will be conducted with participating operators.
- Expected completion date is 3Q 2015.




2012 — 2016

Design | Develop | Test | Deploy

# Our Tool Box

# Mapping on Major Threats

| 17 Hazards That Impact Public Safety (CPUC - March 2012) | |
|---|---|
| **1. Susceptibility of older plastic pipe to premature brittle-like cracking.** | **1%** |
| 2. Grandfathering provisions in 49 CFR Part 192. | |
| **3. Excavation damage by third-parties (dig-ins).** | **3%** |
| **4. Operators unaware of the location and specification of the pipe in the ground.** | **2%** |
| 5. Unmonitored class location change. | |
| **6. Aging infrastructure and interacting threats.** | **7%** |
| **7. Infrastructure, maintenance, and parts.** | **4%** |
| 8. Utility resource management and workforce development | |
| **9. Ineffective or inadequate gas leak identification and response.** | **11%** |
| **10. Pipe with mechanical/strength characteristics susceptible to failure.** | **7%** |
| 11. Lack of protection redundancy. | |
| **12. Lines unable to accommodate in-line inspection tools, such as smart pigs.** | **65%** |
| 13. Utility management deficiencies. | |
| **14. Remote-controlled and automatic shutoff valves.** | **1%** |
| 15. Customer-owned or operated lines. | |
| 16. Master-metered systems not in mobilehome parks. | |
| 17. Inadequate regulation. | |
| **TOTAL** | **100%** |

# Developing a Network of Innovation Champions within Gas Operations

**5+ year**
**5% Part time assignment**

**RDI Fellow**

- Assignment Options:
  - Analyze R&D strategy and project portfolio
  - Voting position in R&D Collaborative Networks and attend conferences
  - Define lab test, field test, and pilot and prepare solution for deployment
- Become a champion for a new technology
- Research and propose new ideas for projects
- Mentor RDI Seniors

**2-4 year**
**5% Part time assignment**

**RDI Senior**

- Assignment Options:
  - Lead for an R&D Project
  - Expert lead for collaboration network
  - Project manager for lab tests, fields tests, or pilot
- Perform need/requirement analysis and build a business case
- Develop ideas into possible new solutions
- Mentor RDI Associates

**0-1 year**
**2 – 6 month part time assignment**

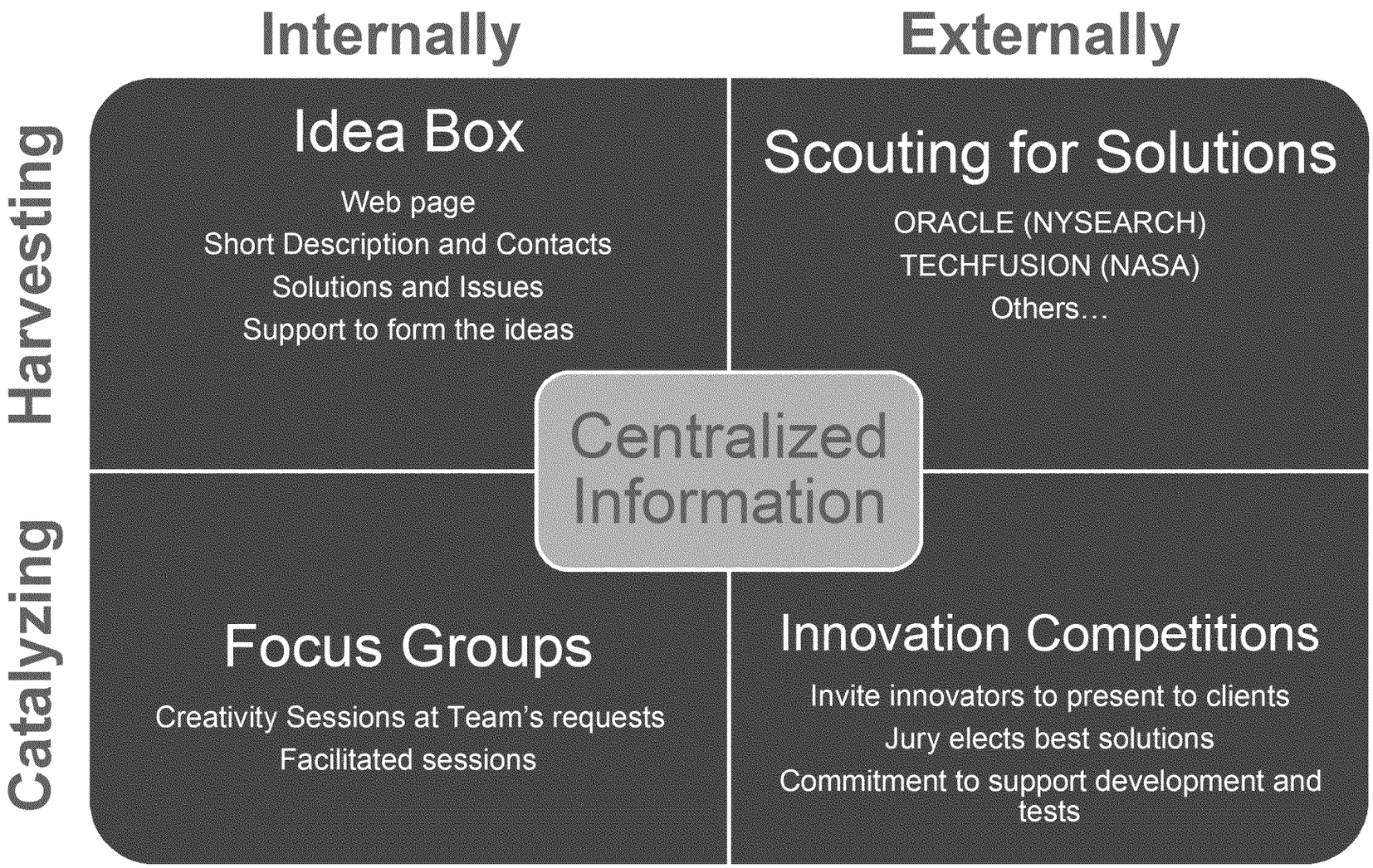
---

Orientation Presentation

**RDI Associate**

- Type of projects:
  - Innovation assessment
  - Technology reviews
  - Test or pilot design, organization and management
  - Development of new procedures and/or training related to new technologies
- Work on assignment 40% of the time (2 days per week)
- Guidance provided by a mentor who has worked on a similar project

# Fostering Innovation

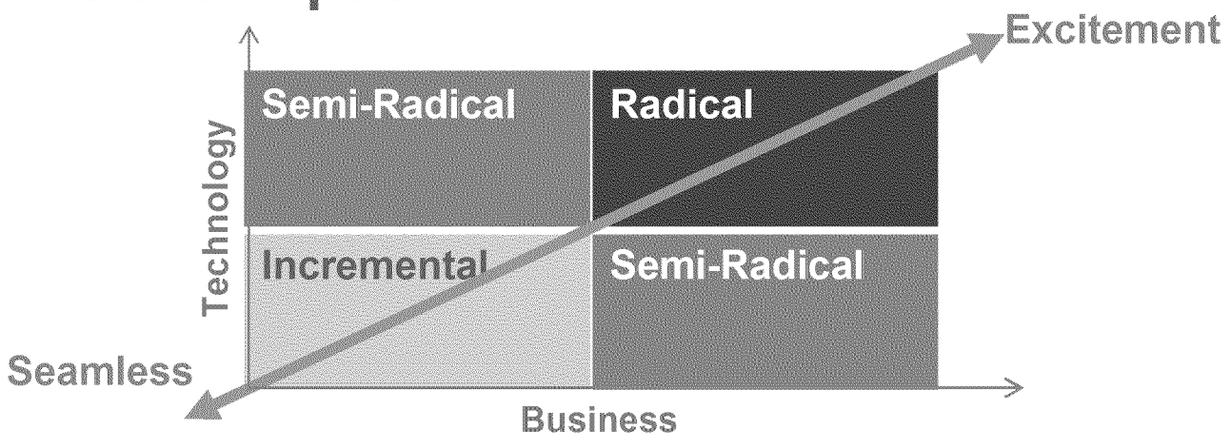


# Driving Deployment

## Define the type of R&D result

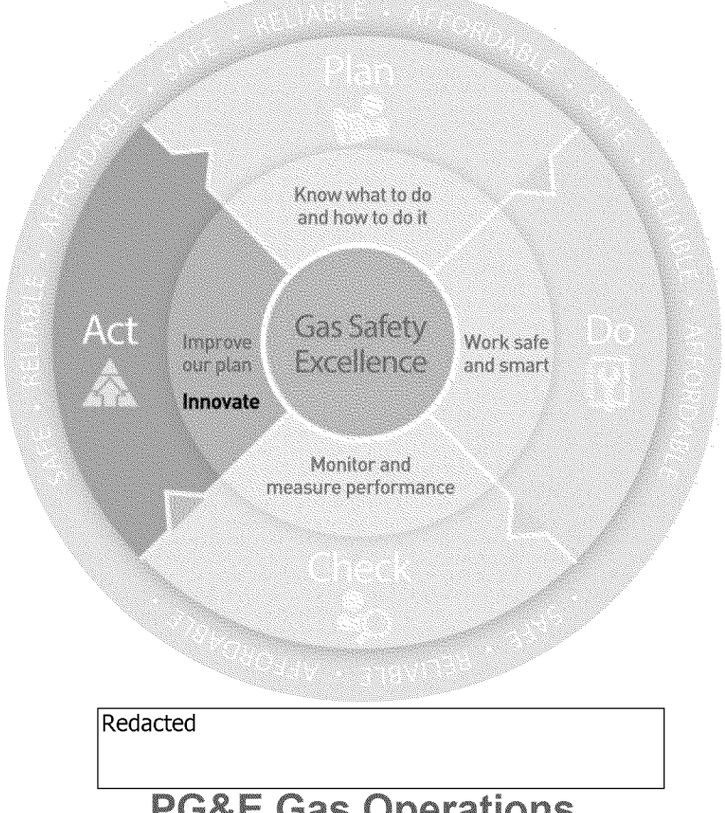
- **Knowledge and Science**: the result influences our gas operation processes through increasing awareness and understanding of teams
- **Know how**: the results are provided as a guide or a reference document or standard to be applied to our gas operation processes
- **Tool**: the results are a software or hardware tool that can be implemented to improve our gas operation processes

## Define the impact




## Operationalize Deployment

# Thank you!

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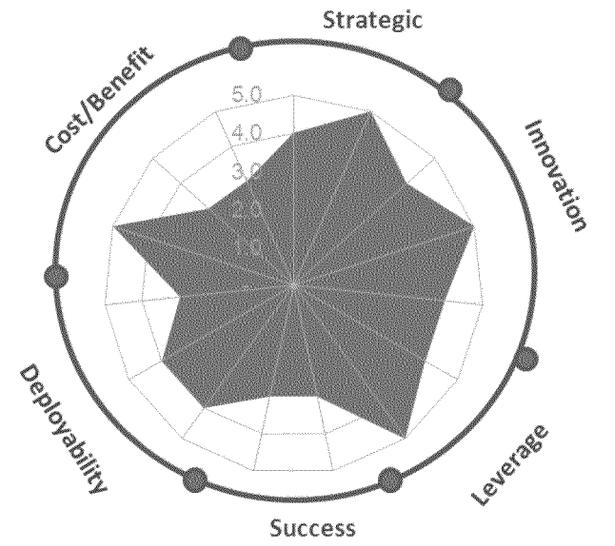
**PG&E Gas Operations**
**R&D and Innovation**

Redacted

# Appendix

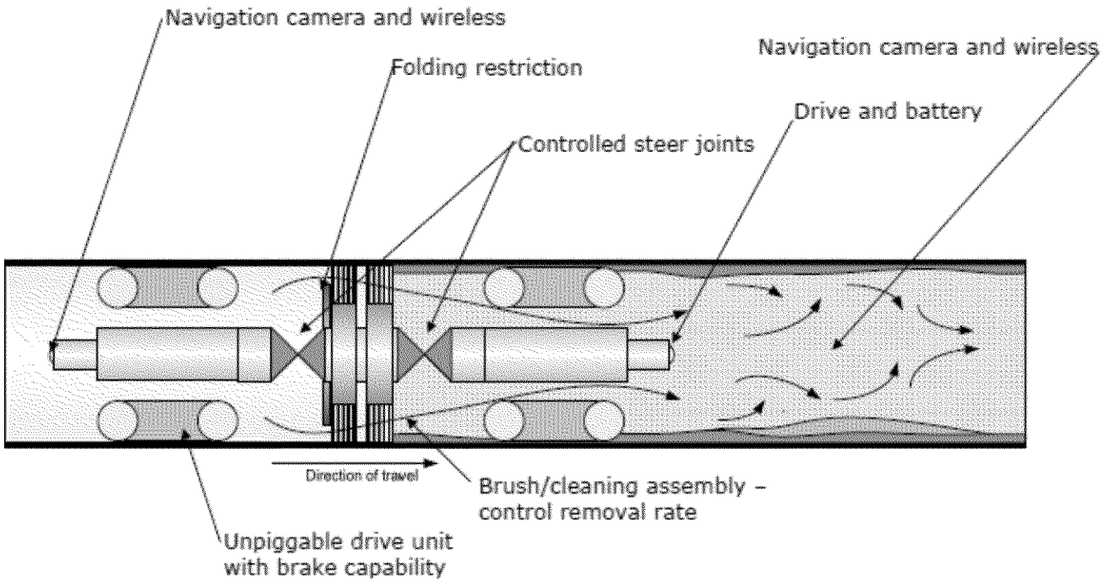
# Project Assessment and Support Sheet

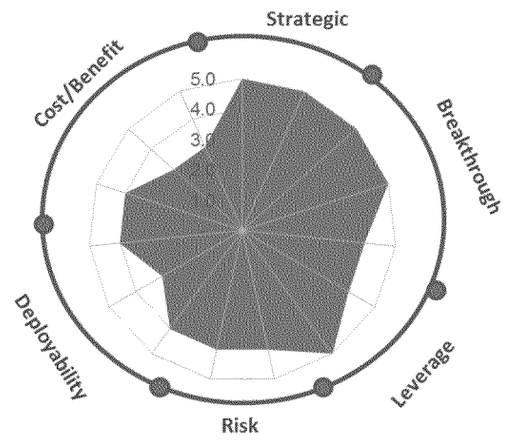
| | |
|---|---|
| Strategy | What issue(s) does it solve? |
| | How does it fit in our overall strategy and rank among our priorities? |
| Innovation | What is the state of the art? |
| | What is the existing solution at PG&E? |
| | How does the team compare to competition? |
| Leverage | How does the project leverage previous work? |
| | What are the opportunities of co-financing? |




| | |
|---|---|
| Chance of Success | What are the risks for failure? |
| | What are the requirements for deployment at PG&E? |
| Deployability | How will the solution be use? |
| | What additional delays have to be accounted for the full deployment? |
| | How does it synchronize with existing actions? |
| Cost vs Benefits | Can we assess cost benefits of the solution? |
| | What will the on-going cost of the solution after deployment be? |
| | What is an acceptable cost target for PG&E? |

# Explorer: Pipeline Cleaning Tool



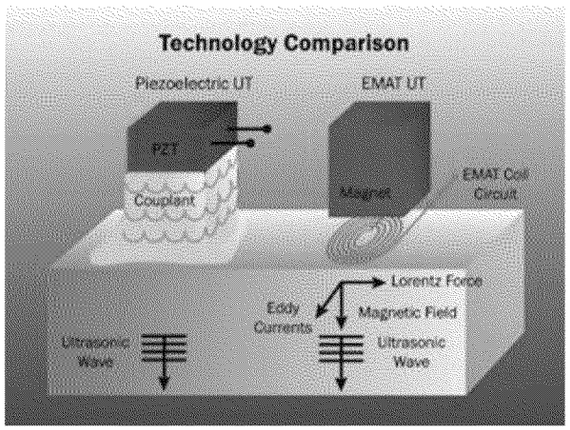




- Debris and liquids can limit the detection and traversing capabilities of Explorer tools in unpiggable pipelines
- Invodane Engineering is developing a Pipeline Cleaning Tool to remove and collect debris prior to Explorer in-line-inspection
- Feasibility study has been completed. Development of prototype is expected to be completed by 2Q 2015.

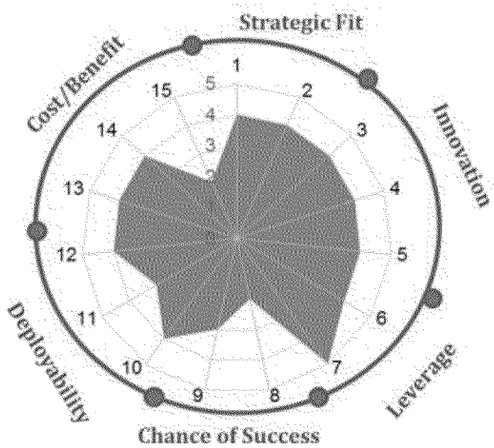
2011 — 2015

Design | Develop | Test | Deploy

# Development of Miniaturized EMAT Sensor




EMAT Technology

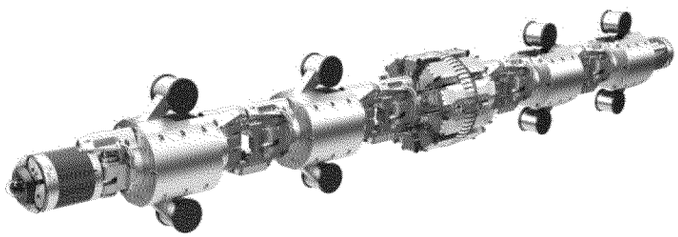



- Electromagnetic Acoustic Transducer (EMAT) for the inspection and characterization of crack-like defects and stress corrosion cracking (SCC) on steel pipelines.
- Currently, EMAT sensors are deployed on pigs, but not yet on platforms for unpiggable pipelines. Invodane Engineering is developing EMAT for its Explorer series of robotic platforms
- Developed by Qi2/Quest Integrity Group, the initial bench-scale prototype of collapsible, bi-directional EMAT sensor will have small form factor to allow integration onto an ILI platform for unpiggable pipelines down to 3” diameter, such as Quest Integrity’s InVista ILI tool

2013 — 2016

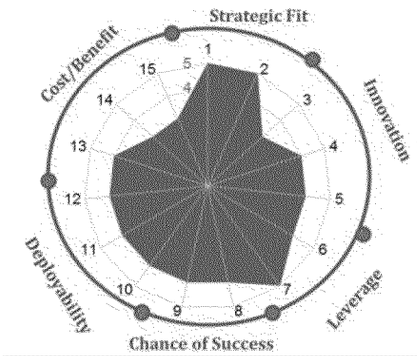
Design | Develop | Test | Deploy

# Explorer 6/8 with MFL and Mechanical Damage Sensors



**Explorer 6/8 with MFL and MDS Sensors**

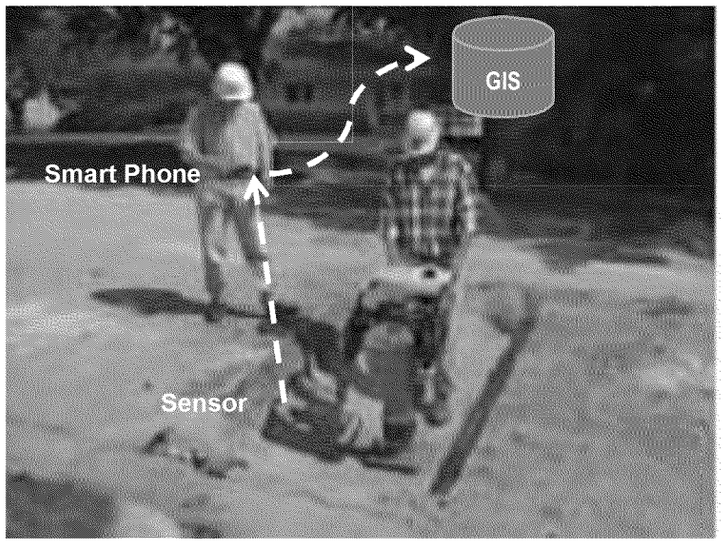
- Current Explorer 6/8 ILI tool for unpiggable pipelines uses a Remote Field Eddy Current (RFEC) sensor
- RFEC is not PHMSA-approved as a suitable ILI tool for integrity management
  - Limitations in differentiating Inner Diameter (ID) and Outer Diameter (OD) defects
  - Limited ability to defect small metal loss defects
- Development of the new Explorer 6/8 platform with Magnetic Flux Leakage (MFL) sensor, which is PHMSA-approved, for metal loss detection and Mechanical Damage Sensor (MDS) for dent and ovality. Both sensors are already integrated on larger Explorer platforms.



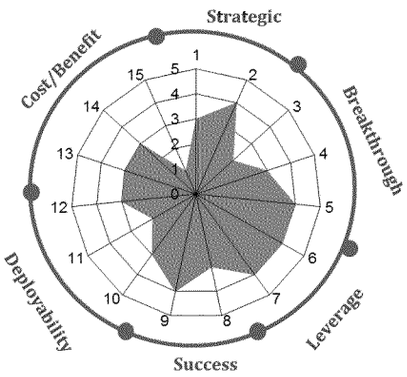

2013 ▼ 2015

Design | Develop | Test | Deploy

# Soil Compaction Supervisor Enhancements




- Soil Compaction Supervisor informs crew about the adequate compaction of excavation back filling
- It leverages new user interface through smart phones and tablets, GPS localization, and remote connection to automatically upload information in utility's database
- The project will also reduce costs by demonstrating that results are equivalent to onerous traditional nuclear densitometer


2014 ▼ 2015

Design | Develop | Test | Deploy