R&D and Innovation for PG&E Gas Operations

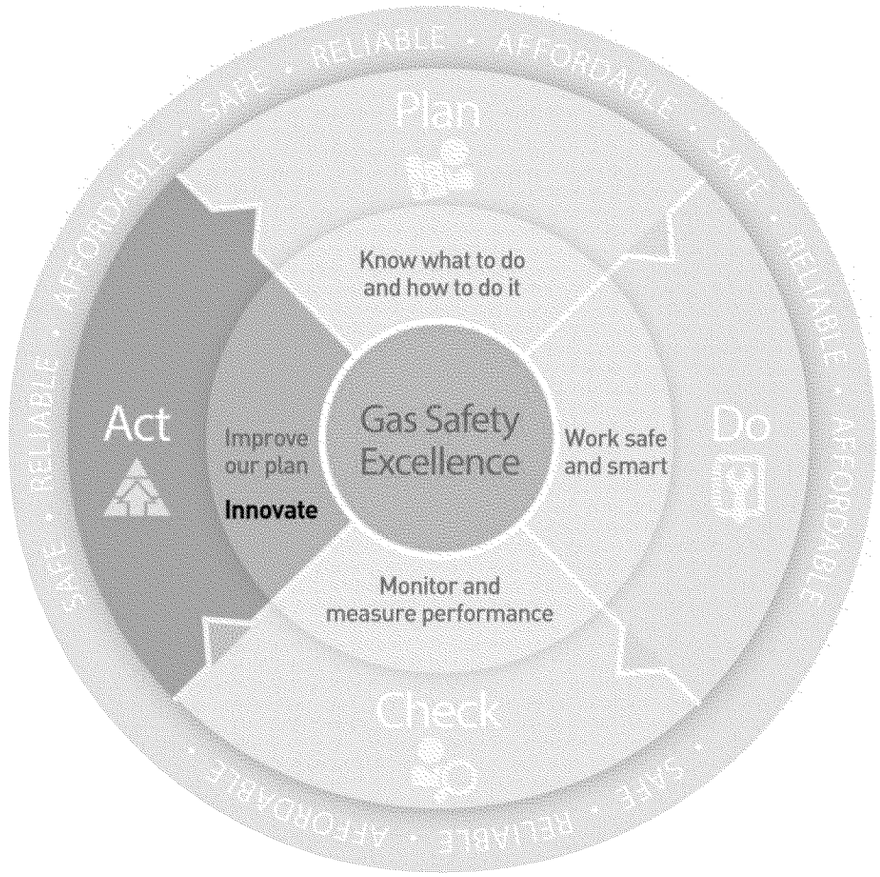
Redacted

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]

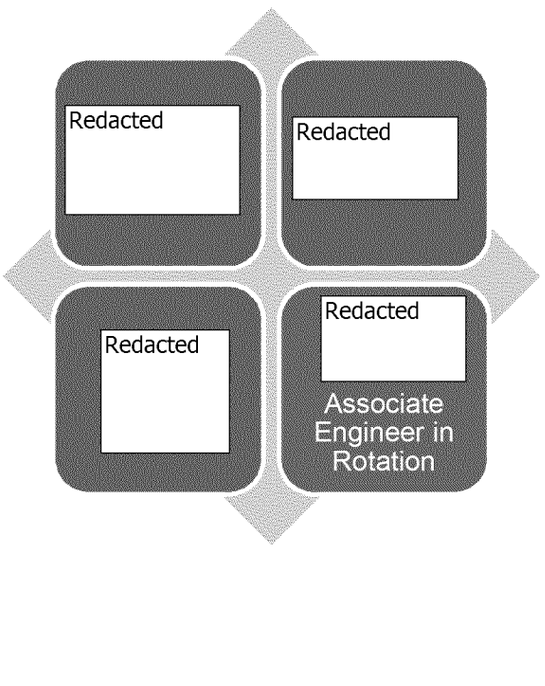
- PG&E is introducing a systematic risk based management of its assets following the continuous improvement Plan, Do, Check, Act sequence.
- R&D and Innovation is part of the Act step.

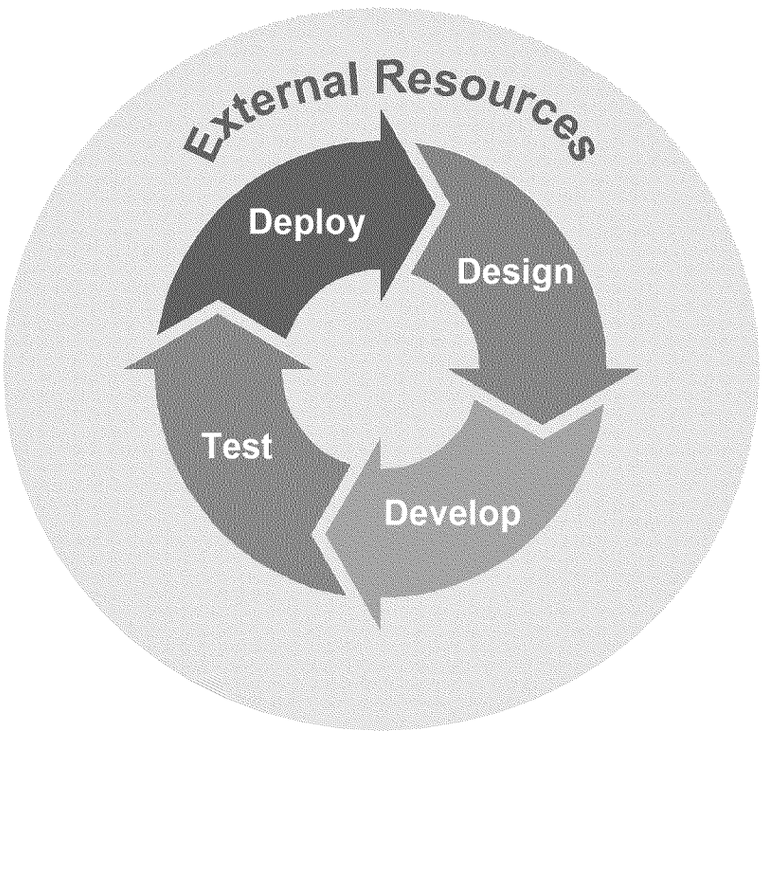


[1]: Letter to the Chairman of NARUC on April 30th, 2013

Mission Statement

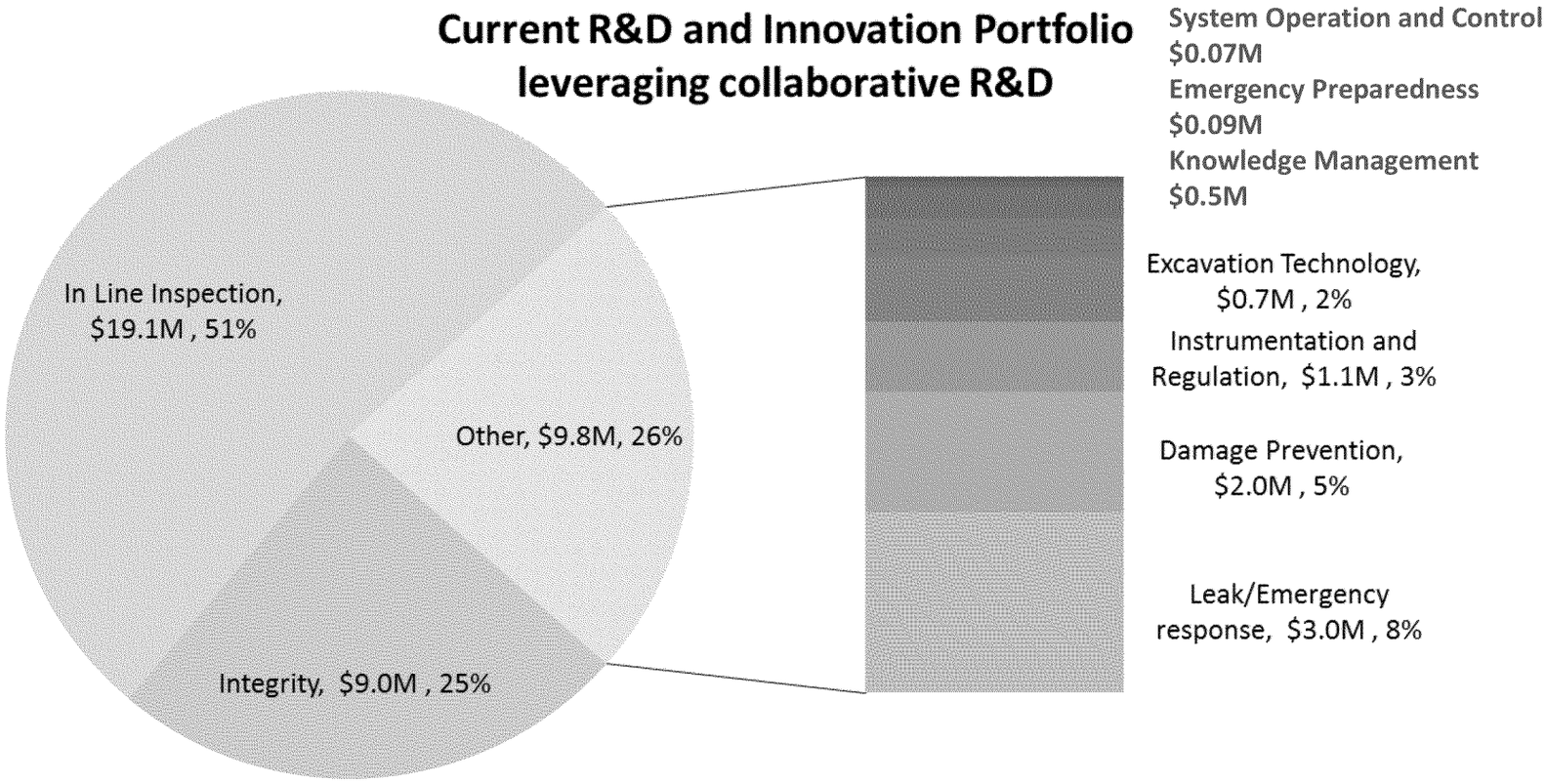
R&D and Innovation detects, adapts, qualifies and implements innovative solutions in the Gas Operations business to improve its performance measured in public and work safety, customer satisfaction, cost effectiveness, environmental impact, regulatory compliance, and communication.





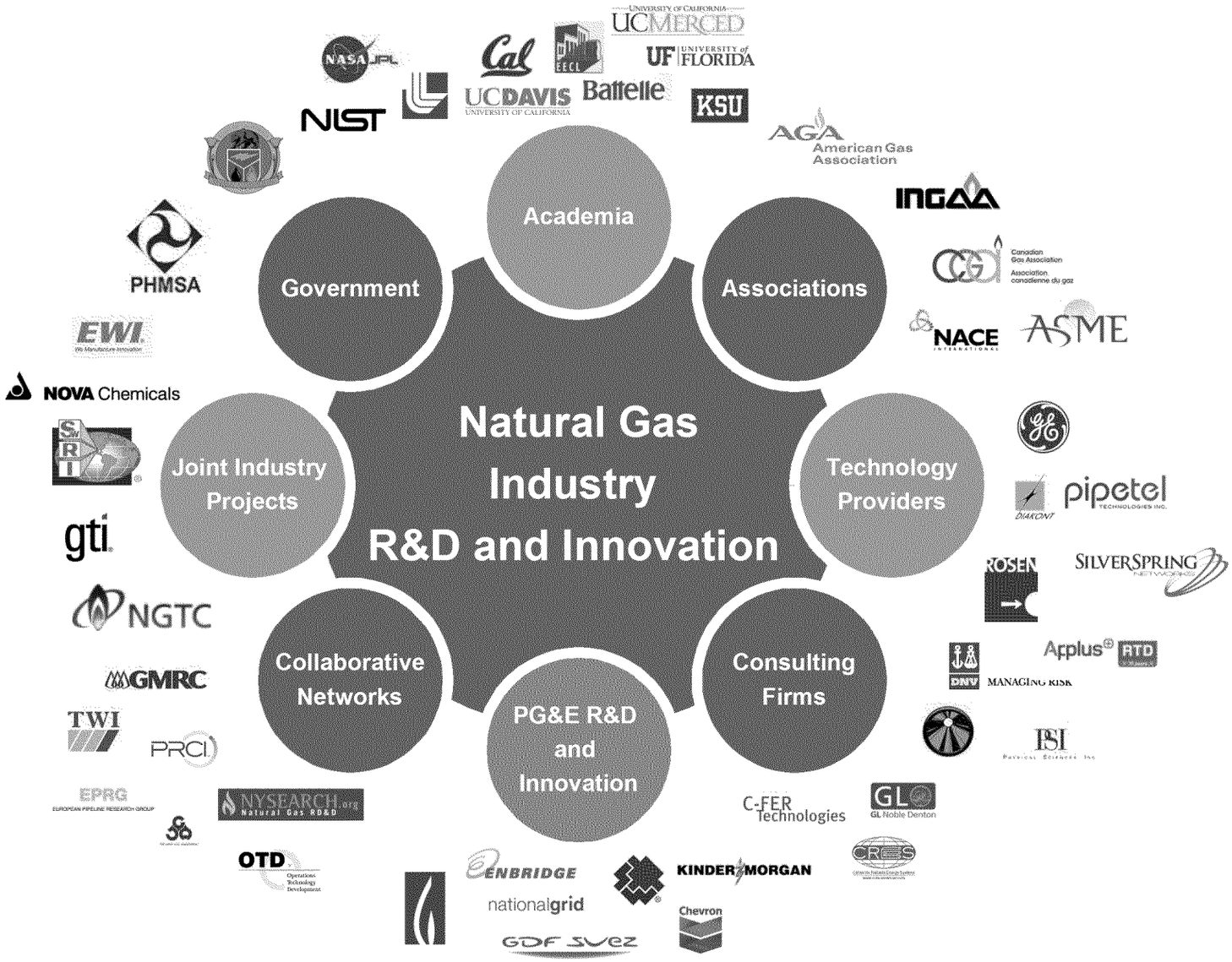
R&D and Innovation Portfolio

- 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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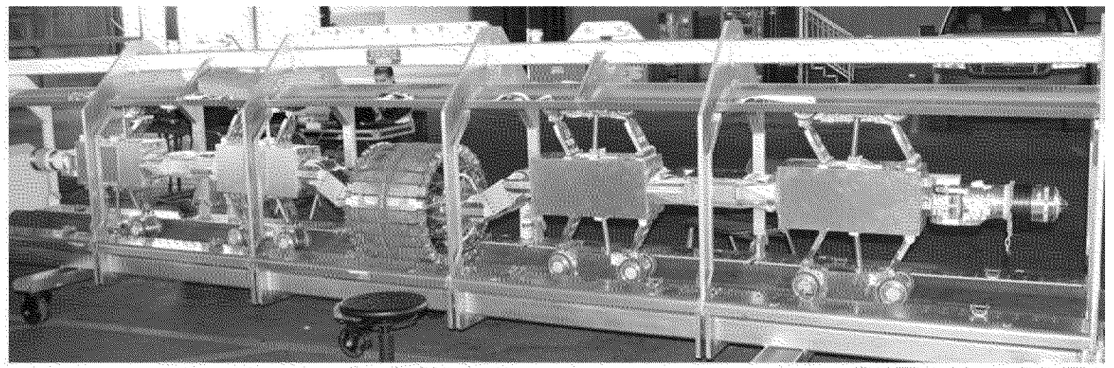
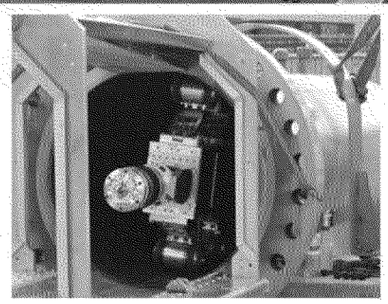
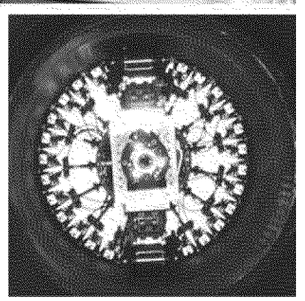






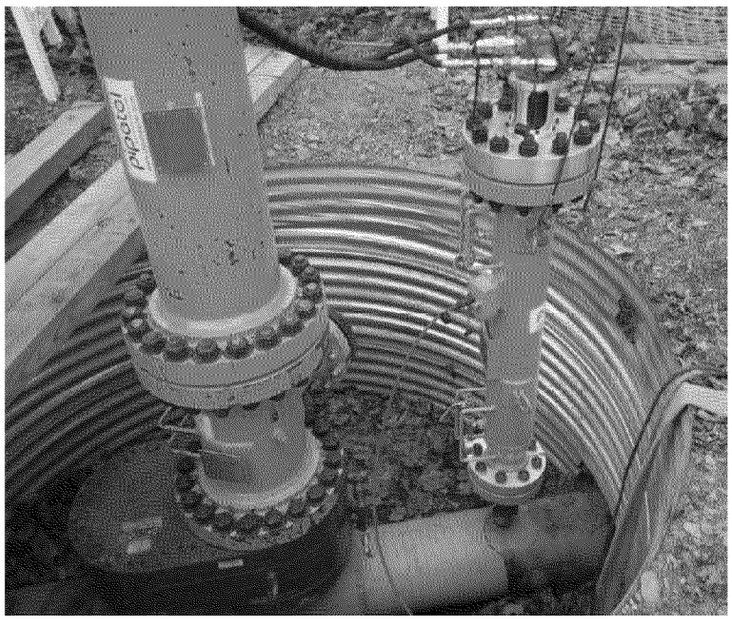
Line-153 at Irvington Station in Fremont

- 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



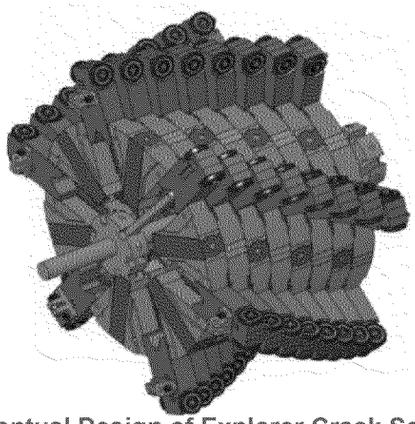
- Tool used for charging the batteries of Explorer robotic tools through a hot tap.
- Eliminates costly removal of the robot to charge the batteries.
- Two versions developed: generator and battery powered charger.
- In-line charging tool has been deployed and used commercially (Explorer 10/14 was charged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

2011 2013

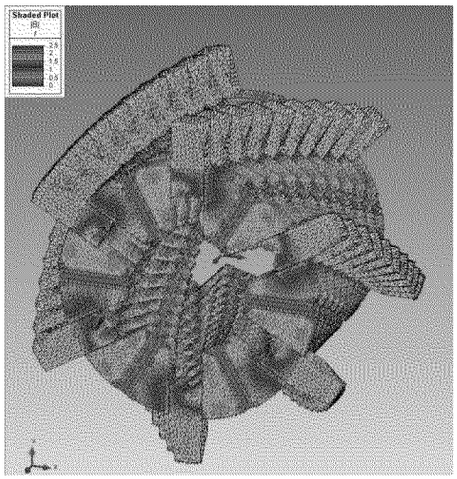
Design | Develop | Test | Deploy

Completed

Explorer – Crack Sensor

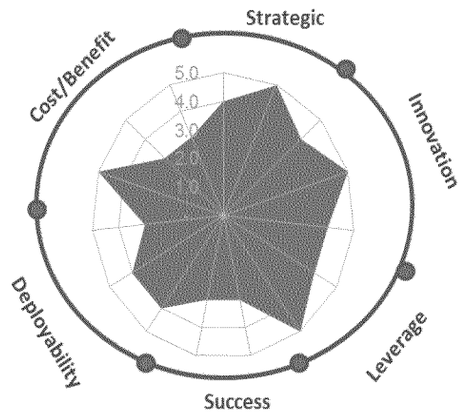


Conceptual Design of Explorer Crack Sensor



Magnetic field generated by spiral TMFL sensor

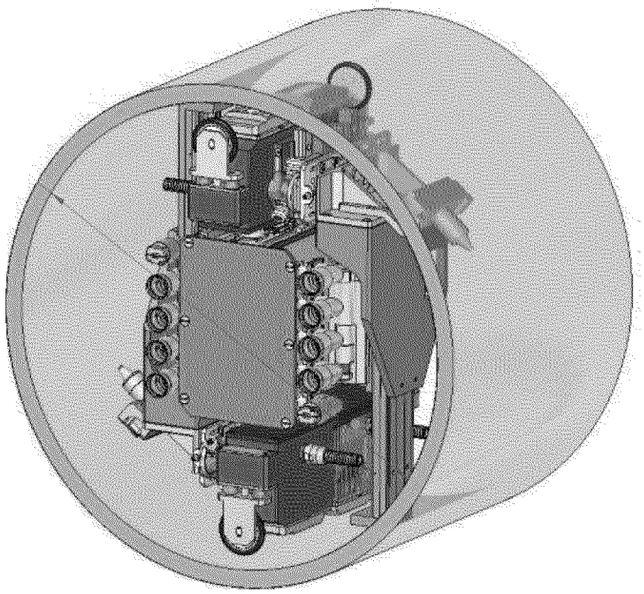
- Development of sensors for the detection of axially oriented cracks, primarily in the long seam weld.
- The design incorporates Electromagnetic Acoustic Transducer (EMAT), and Transverse Magnetic Flux Leakage (TMFL) sensors in a spiral configuration.
- Initial development will be on the Explorer 20/26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



2011 — 2015

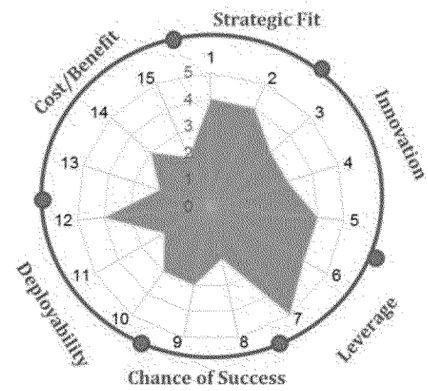
Design | Develop | Test | Deploy

Diakont Multiple Channel EMAT



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

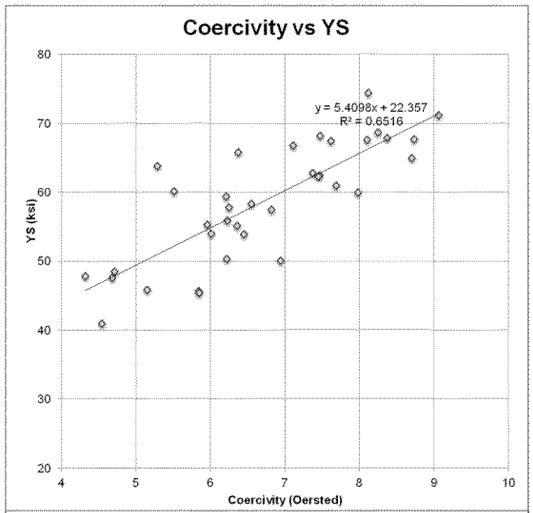
- Multi-channel EMAT sensor to allow inspection, characterization, and measurement of girth welds.
- Sensor integrated onto Diakont's tethered crawler to inspect 30"-56" diameter pipelines.
- Demonstration of test unit in PG&E territory in 2Q 2014
- Commercial availability in ~ 3Q 2014.
- Result will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

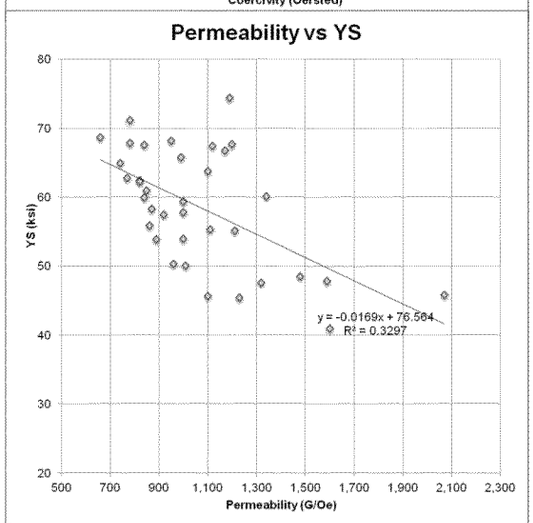


2010 — 2014

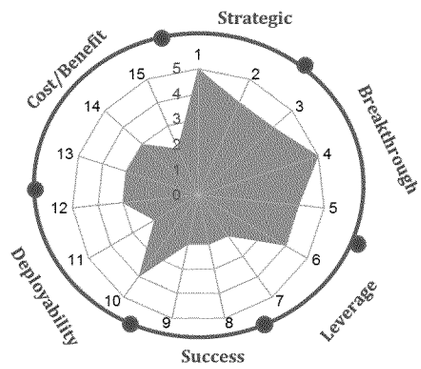
Design | Develop | Test | Deploy

Material Characterization





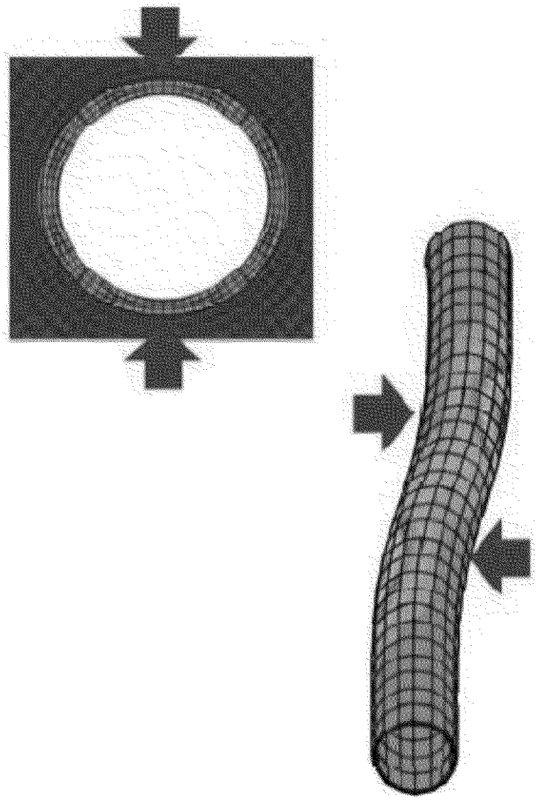
- Co-funded with PHMSA, to improve knowledge about buried pipelines through In Line Inspection and to complement PRCI project NDE-4A.
- Pipeline microstructural parameters of interest:
  - Yield strength
  - Tensile strength
  - Transition temperature
  - Fracture toughness
- Some proposed techniques 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

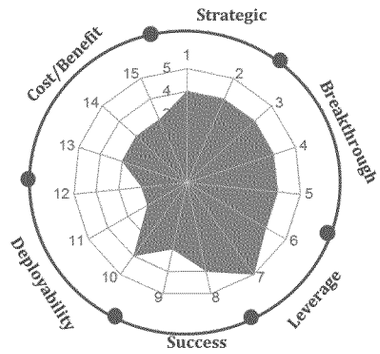
Design | Develop | Test | Deploy

Improving MFL Storage Well Casing Assessments



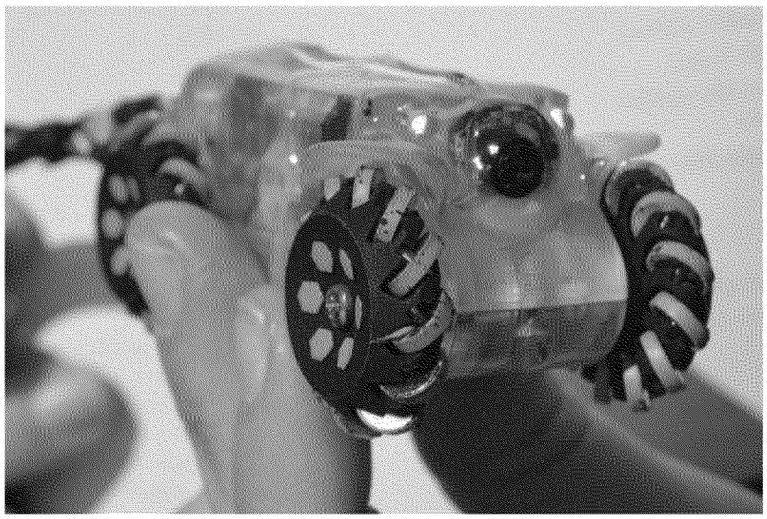
Example of Geo-mechanical Loads on Downhole Pipe

- 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



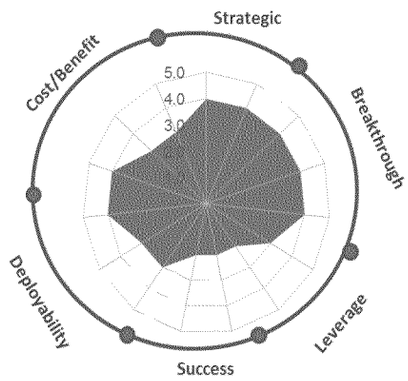
2013 Design → Develop → Test → 2016 Deploy

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

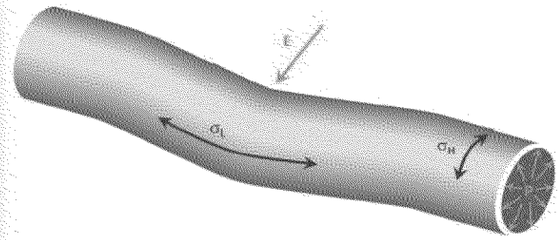
Design → Develop → Test → Deploy

Integrity Management

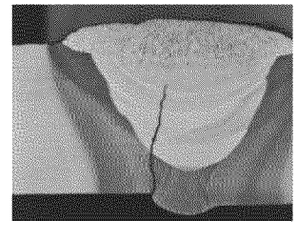
Joint Industry Project on Ground Movements

- 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

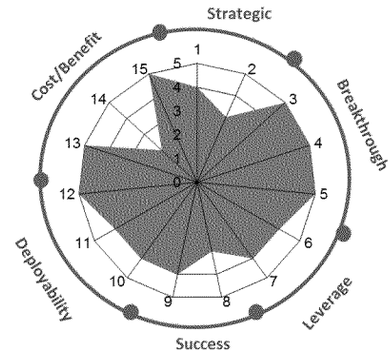
Pipe Movement
→ Strain (ε) & Stress (σ_L)



Bending Strain & Stress
+
Girth Weld Features
!



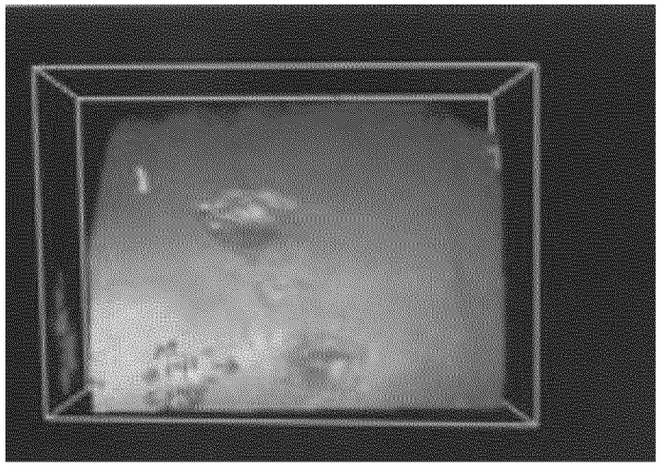
- Study led by Center for Reliable Energy Systems (CRES)
  - Girth weld failures on vintage pipelines
  - Additional stresses exerted on pipelines (ground movement, residual stresses, construction activities, soil creep, heavy rainfall, etc.)
  - Characterization of pre-existing flaws on girth welds from welding (lack of penetration, hydrogen embrittlement, high-low misalignment, cracking, etc.)



2012 — 2014

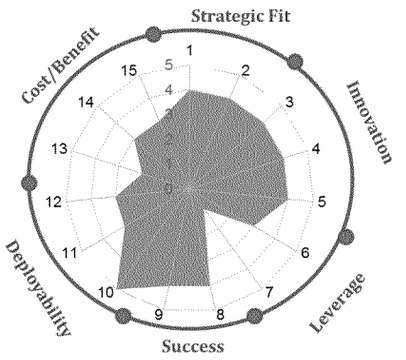
Design → Develop → Test → Deploy

Stereoscopic Camera to capture 3-D Images of Features



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

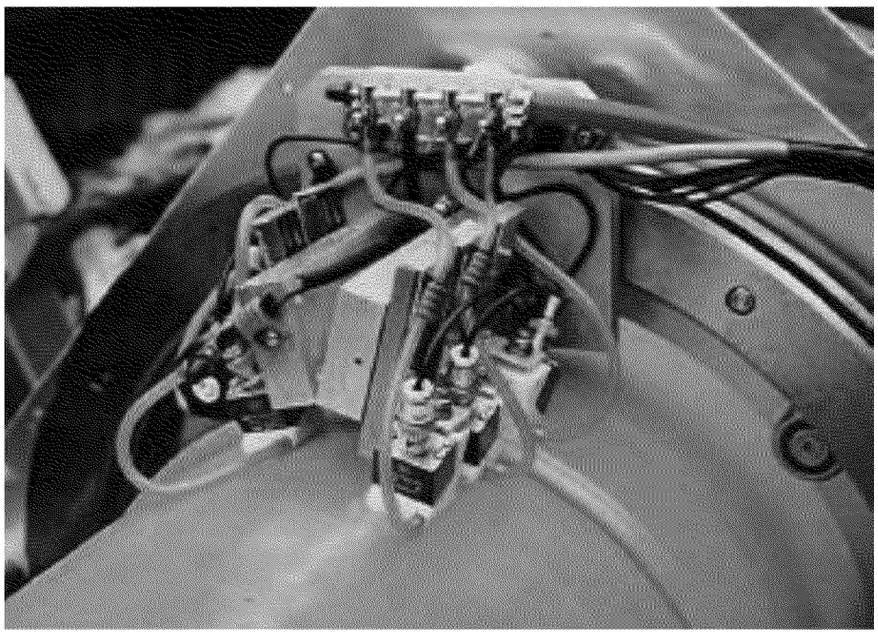
- PRCI detected the technology through the NASA Tecfusion program
- Spin-off of University of Kentucky
- Projector and receiver integrated in the camera
- Projects about 600 frames on the object to measure the volume in one picture
- Automatically creates data for calculations of RSTRENG per ASME B31G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



2012 — 2014

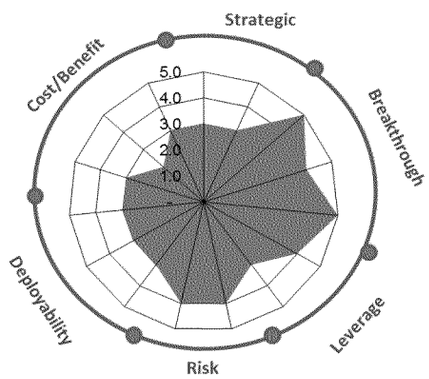
Design | Develop | Test | Deploy

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

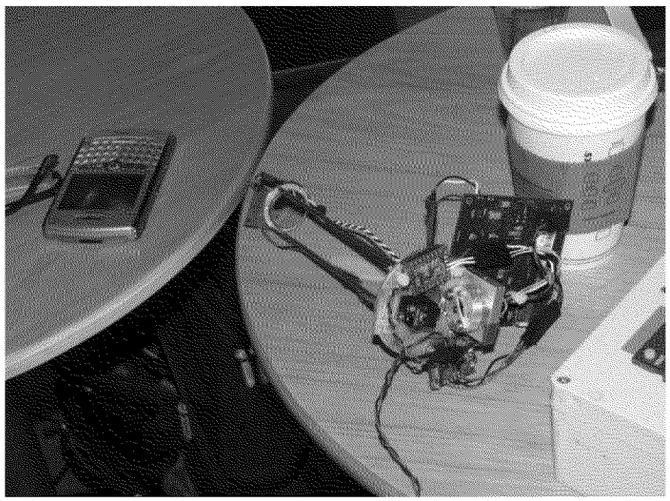
Redacted

- 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

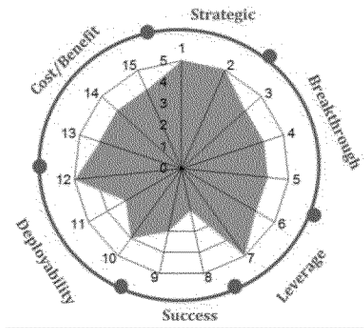
Design | Develop | Test | Deploy

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.

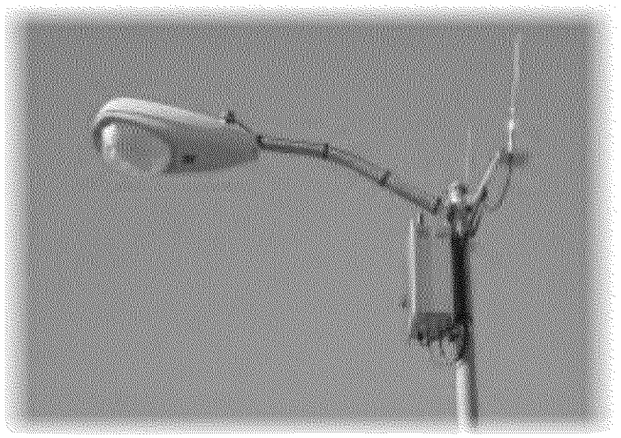
2013 2014

Design | Develop | Test | Deploy

Completed

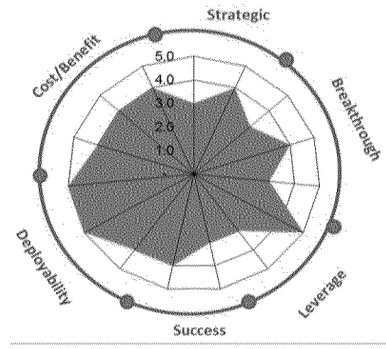
System Operation and Control

Using Smart Meter Infrastructure to transport Monitoring Data



ERX Unit and Data Collector Unit

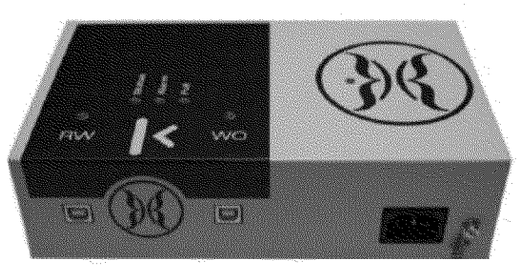
- Cost effective alternative to cellular service or dedicated wireless network.
- Demonstrated that in adequate locations, latency is shorter than few seconds.
- Installed Silverspring Networks modem on ERX to collect and transport local pressure information towards the Control Room.
- Field test completion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

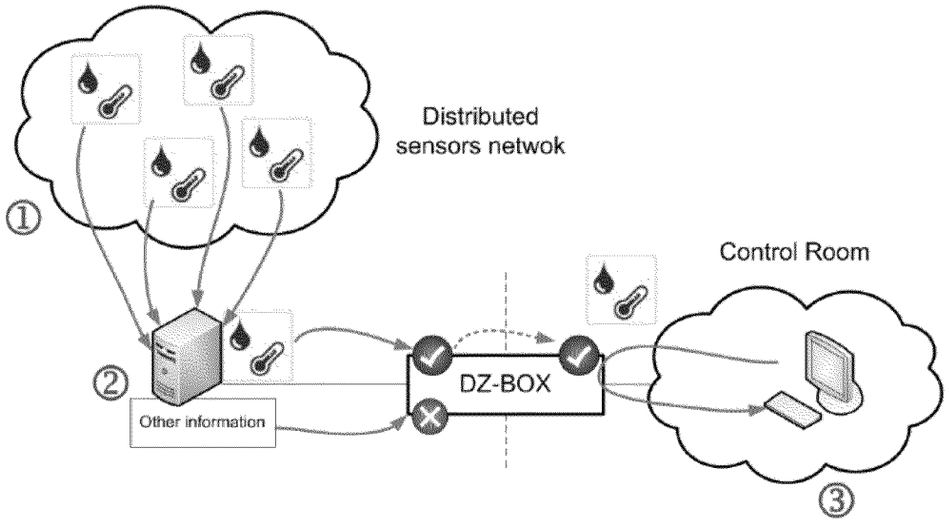


2012 2014

Design | Develop | Test | Deploy

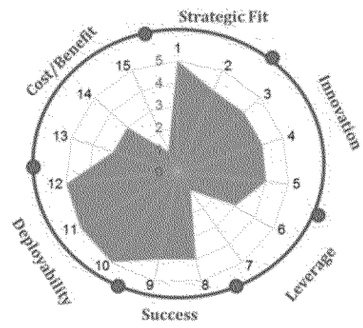
Separating our Control Room from Public Networks





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

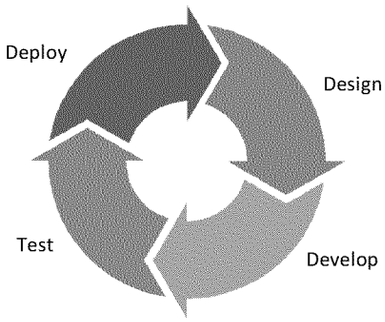
Design | Develop | Test | Deploy

Damage Prevention

Road Maps

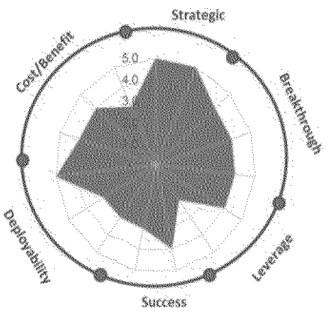
Objectives	Needs and Gaps	R&D Projects and Technologies
Damage Prevention	Time line	<2012 | 2012 | 2013 | 2014 | 2015 | >2015
Prevent 3rd Party Damage	Detect Construction Equipment/Activity	Satellite Observation (PRCI)
		● Aerial Surveys - Drones (PRCI)
		● Image Analysis (PRCI)
		Optic Fiber (Cost Reduction) (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

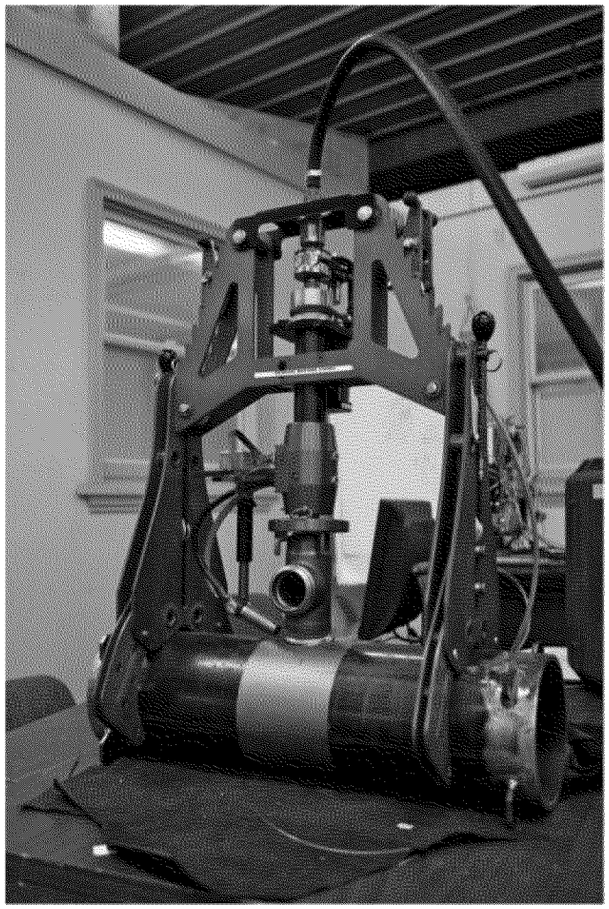


2013 2014

Design | Develop | Test | Deploy

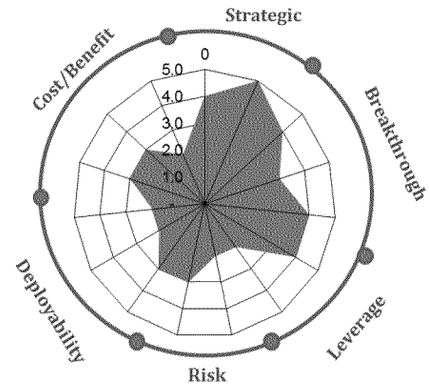
Excavation and Construction Technologies

Automated Welder for Laterals



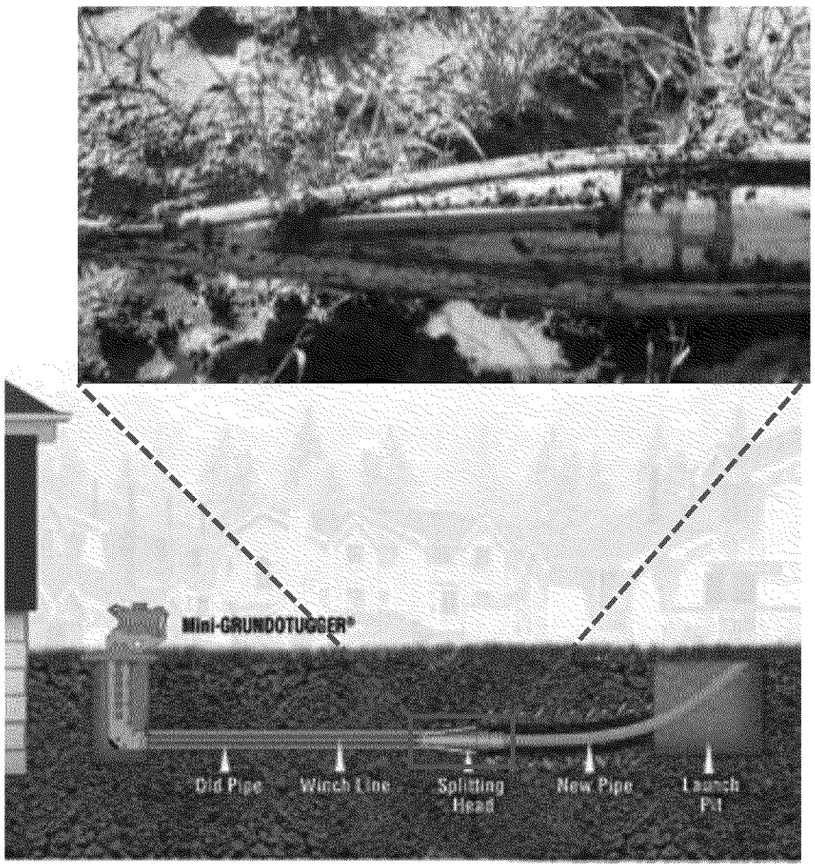
Prototype of Automated Welding Unit
(Ref: GTI, Dennis Jarnecke)

- 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



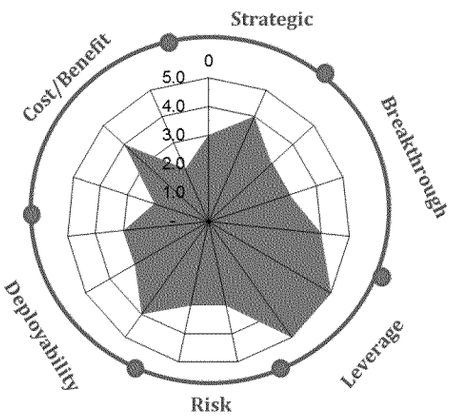
2010 — Design | Develop | Test | 2015 — Deploy

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.

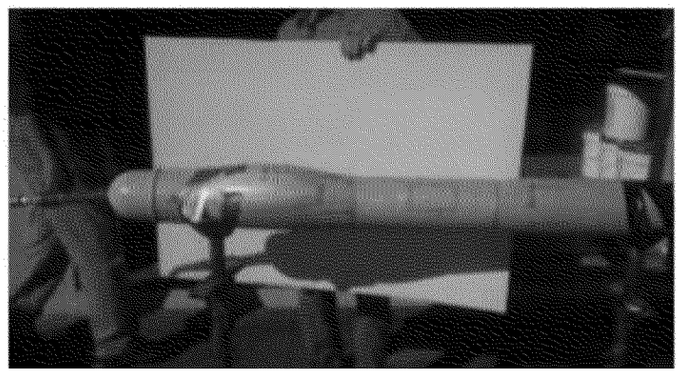


2012 — 2015

Design | Develop | Test | Deploy

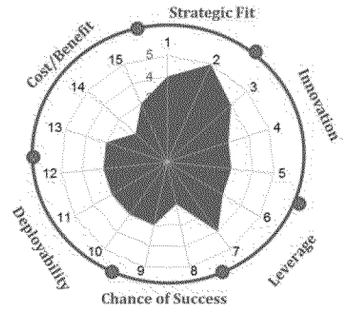
Composite Repair on Polyethylene Pipe

Composite repair trial on polyethylene pipe.



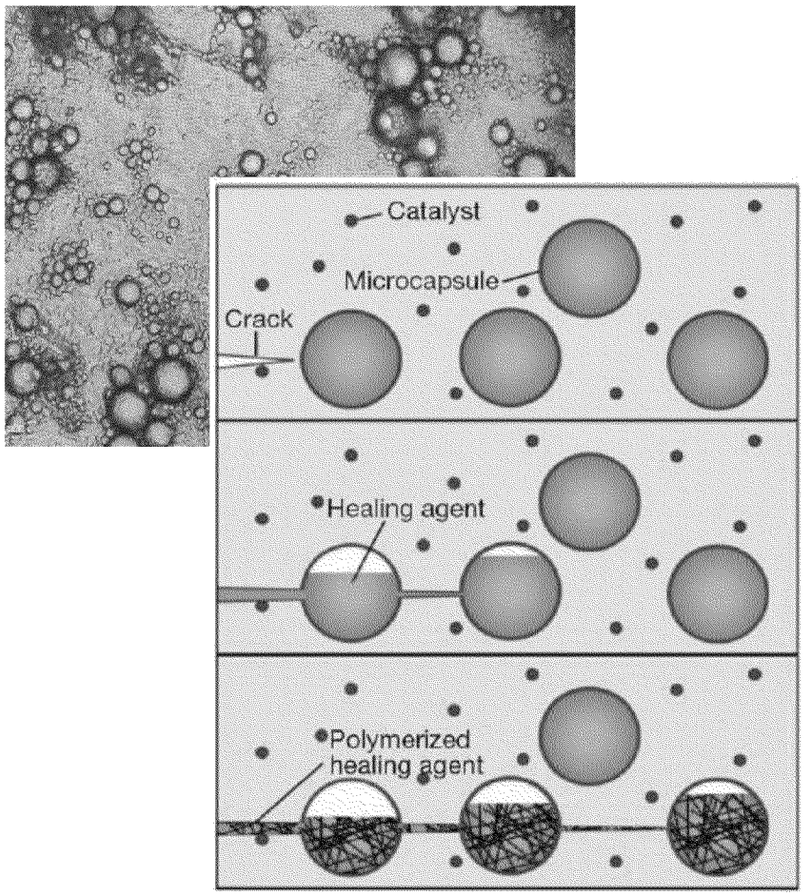
Hydrostatic pressure test on repaired sample; failure outside of repair area.

- 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 — Design | Develop | Test | Deploy — 2015

Self-Healing Material and Pipe Development



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

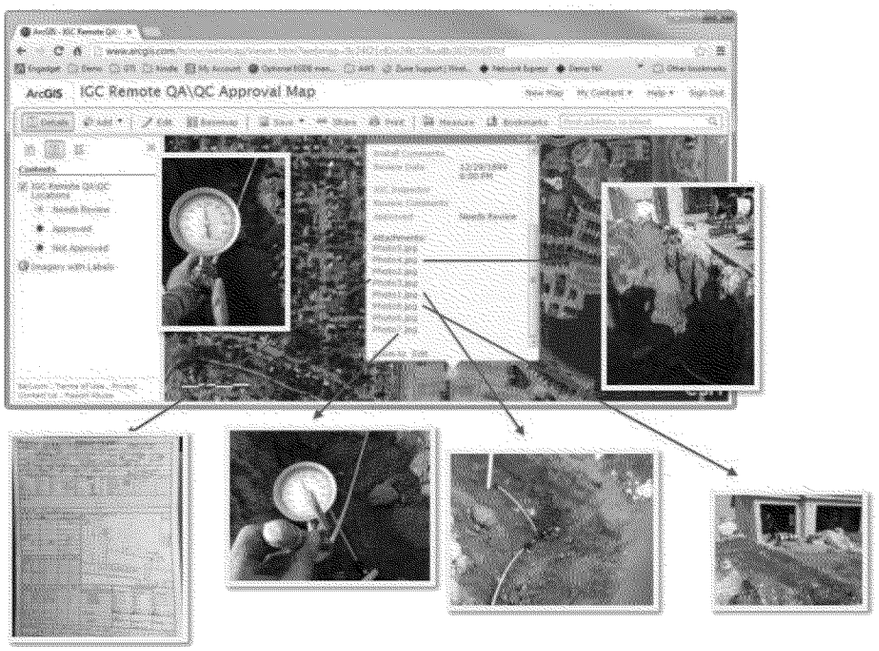
- First academic research results in 1996 for polymer matrix of composite materials
- Microcapsules containing self-healing agent embedded into PE matrix
- Cracks rupture microcapsules, activating healing agent, which prohibits further crack propagation.
- Current work is focused on proof of concept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

2012 2020

Design | Develop | Test | Deploy

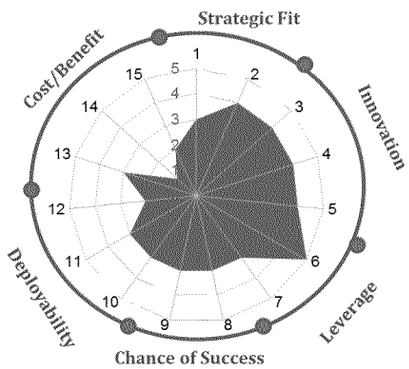
In Evaluation

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

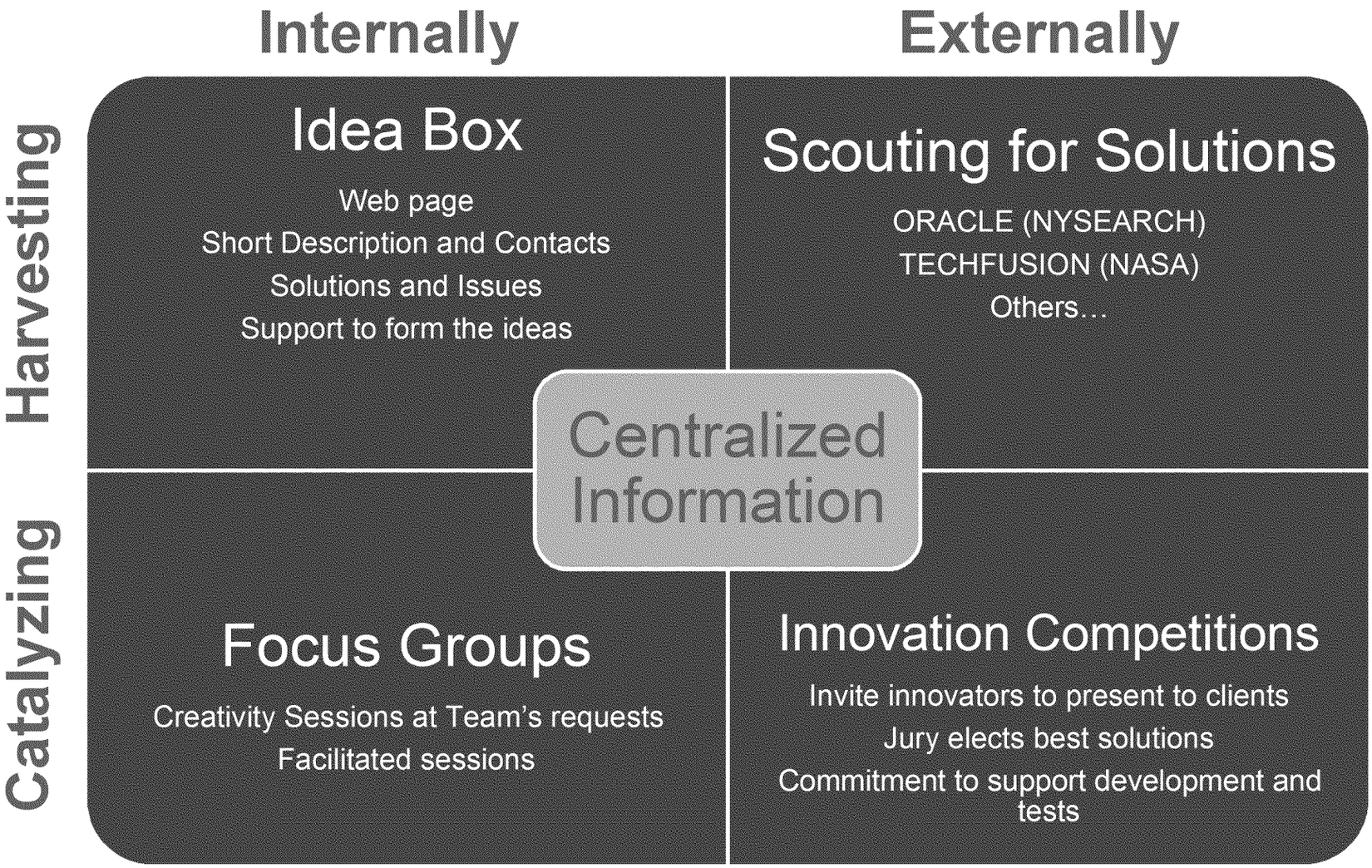
0-1 year
2 – 6 month part time assignment

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

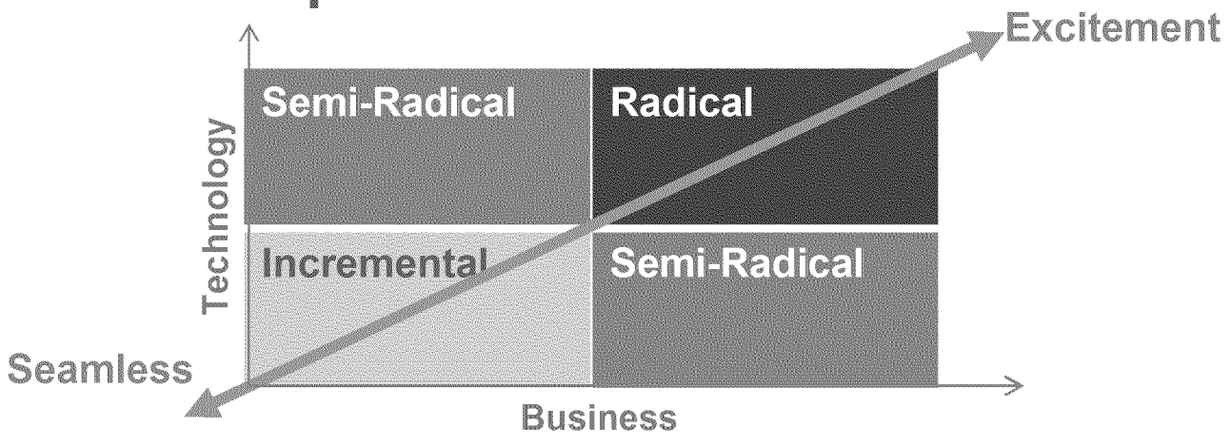


Driving Deployment

Define the type of R&D result

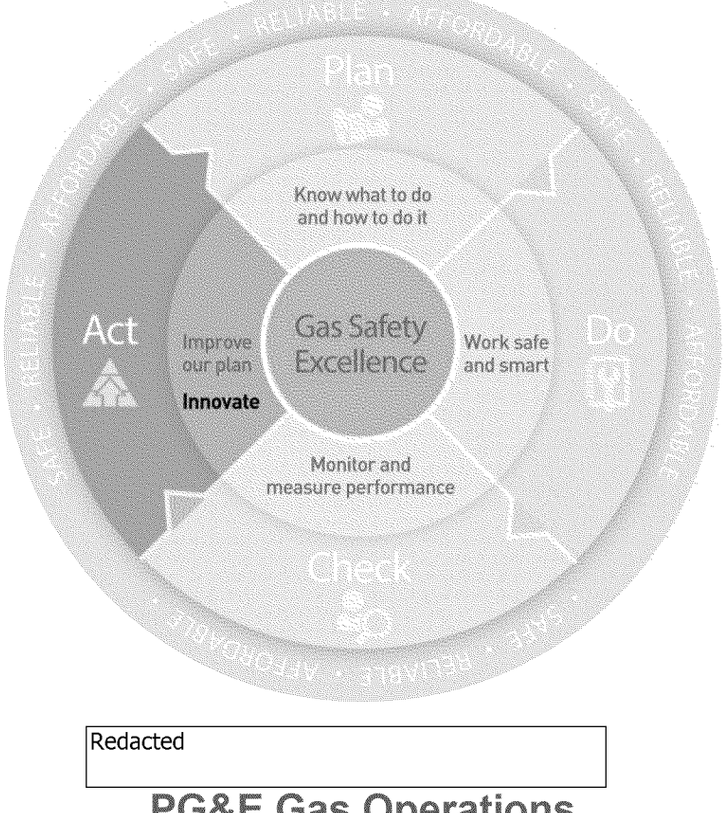
- **Knowledge and Science**: the result influences our gas operation processes through increasing awareness and understanding of teams
- **Know how**: the results are provided as a guide or a reference document or standard to be applied to our gas operation processes
- **Tool**: the results are a software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

Define the impact



Operationalize Deployment

Thank you!



Redacted

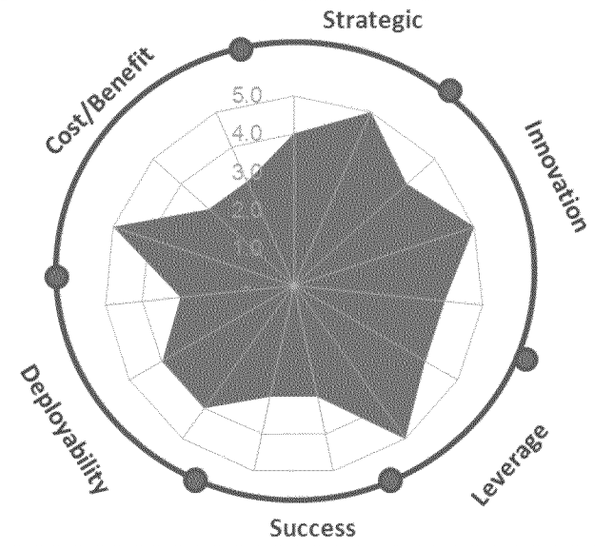
PG&E Gas Operations
R&D and Innovation

Tel: Redacted
Cel: Redacted
E-mail: Redacted

Appendix

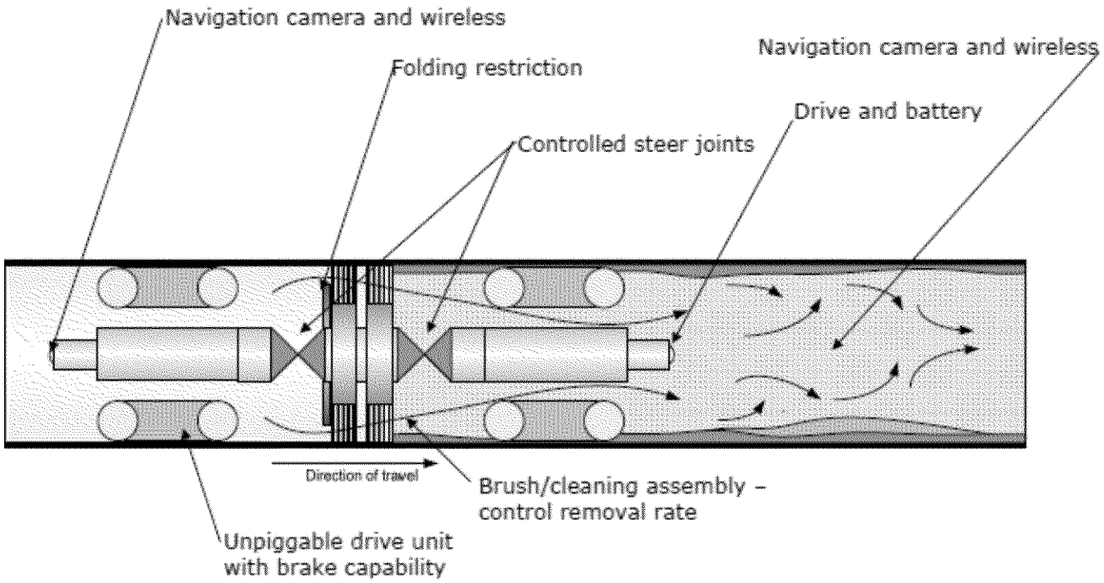
Project Assessment and Support Sheet

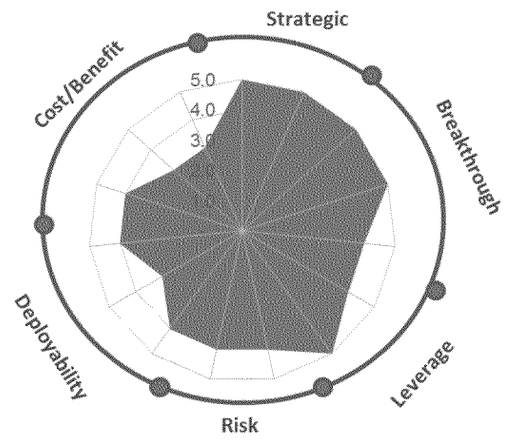
Strategy	What issue(s) does it solve?
	How does it fit in our overall strategy and rank among our priorities?
Innovation	What is the state of the art?
	What is the existing solution at PG&E?
	How does the team compare to competition?
Leverage	How does the project leverage previous work?
	What are the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



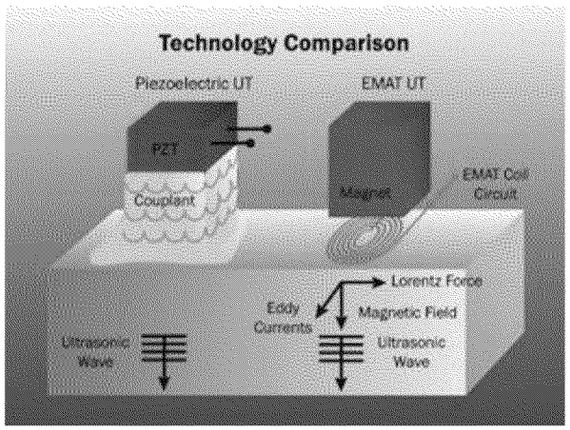


- Debris and liquids can limit the detection and traversing capabilities of Explorer tools in unpiggable pipelines
- Invodane Engineering is developing a Pipeline Cleaning Tool to remove and collect debris prior to Explorer in-line-inspection
- Feasibility study has been completed. Development of prototype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

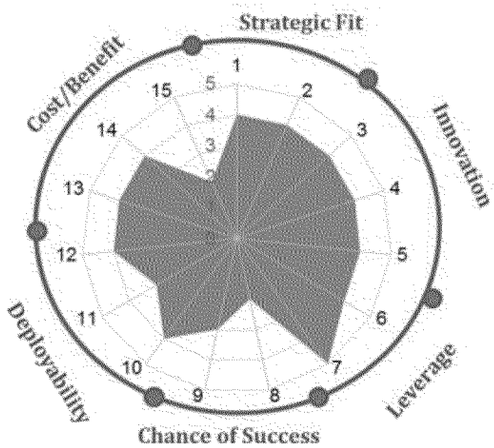
2011 — 2015

Design | Develop | Test | Deploy

Development of Miniaturized EMAT Sensor



EMAT Technology

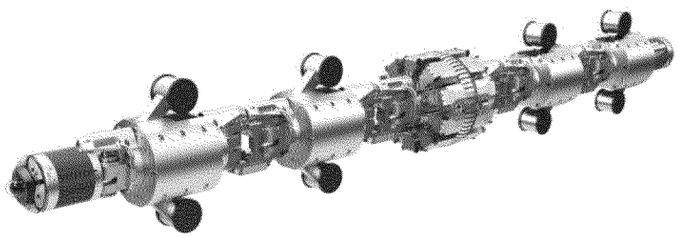


- Electromagnetic Acoustic Transducer (EMAT) for the inspection and characterization of crack-like defects and stress corrosion cracking (SCC) on steel pipelines.
- Currently, EMAT sensors are deployed on pigs, but not yet on platforms for unpiggable pipelines. Invodane Engineering is developing EMAT 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

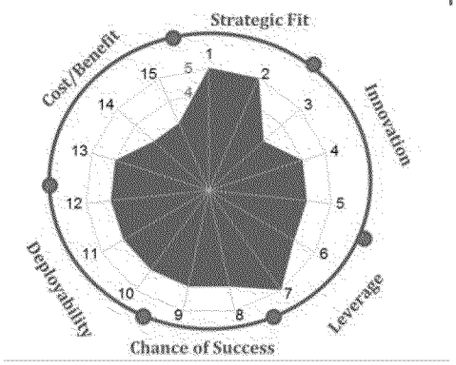
Design | Develop | Test | Deploy

Explorer 6/8 with MFL and Mechanical Damage Sensors



Explorer 6/8 with MFL and MDS Sensors

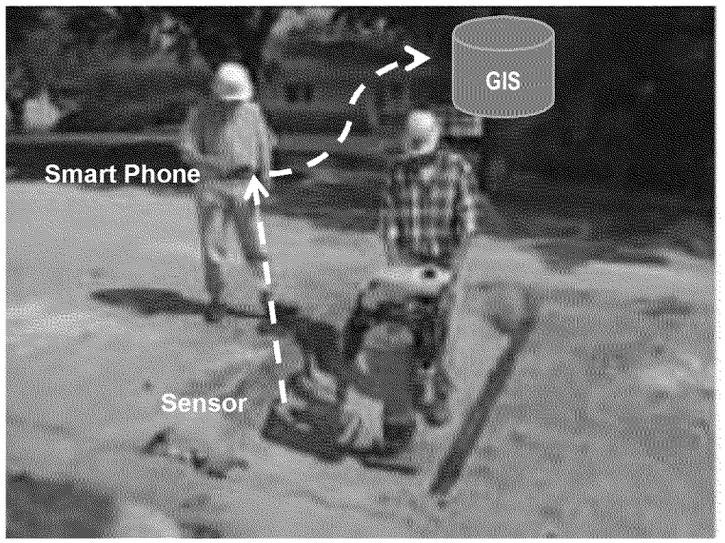
- Current Explorer 6/8 ILI tool for unpiggable pipelines uses a Remote Field Eddy Current (RFEC) sensor
- RFEC is not PHMSA-approved as a suitable ILI tool for integrity management
  - Limitations in differentiating Inner Diameter (ID) and Outer Diameter (OD) defects
  - Limited ability to defect small 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.



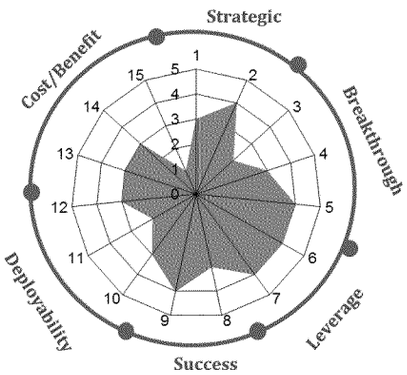
2013 ▼ 2015

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