R&D and Innovation for PG&E Gas Operations

François Rongere
2014 West Regional Gas Conference, Tempe (AZ), August 20th, 2014
Pacific Gas and Electric Company, incorporated in California in 1905, is one of the largest combination natural gas and electric utilities in the United States.

The company provides natural gas and electric to approximately 15 million people throughout a 70,000-square-mile service area in northern and central California.

Service area stretches from Eureka in the north to Bakersfield in the south, and from the Pacific Ocean in the west to the Sierra Nevada in the east.

Gas Operation Key Statistics
- ~ 5,800 miles of gas transmission pipeline
- Approx. 42,000 miles of gas distribution pipe
- 4.3 million natural gas customer accounts.
- Deliver 970 BCF/year (2.6 BCF/daily average)
Jeff Wiese recently pointed out the importance of R&D and Innovation to improve the safety of Transmission and Distribution infrastructure cost effectively

PG&E is introducing a systematic risk based management of its assets following the continuous improvement Plan, Do, Check, Act sequence.

PG&E Gas Operations received the ISO 55001 certification in May 2014.

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.

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Associate Engineer in Rotation

External Resources

Deploy
Design
Test
Develop
Natural Gas System Overview

1. **NATURAL GAS WELLS**
   - PG&E does not have production fields nor processing plants

2. **PROCESSING PLANTS**
   - 42,000 miles of main
   - 3 millions of service lines
   - Associated Equipment

3. **COMPRESSOR STATIONS**
   - 9 Compressions Stations
   - 184,000 HP
   - 4 Dehydrator Stations

4. **GAS STORAGE FACILITY**
   - 3 underground storage
   - 106 bcf

5. **TRANSMISSION LINES**
   - 5,800 miles of transmission pipelines
   - Operated from 60 PSI to 1,000 PSI

6. **REGULATOR STATIONS**
   - 2,200 regulators
   - Stations in the Distribution system

7. **SAFETY VALVE MONITORS**

8. **DISTRIBUTION SYSTEM**

9. **GAS CONTROL CENTER**
   - 4.3 millions customers

R&D and Innovation driven by Risk Analysis of each Asset Family
96 active projects, 138 in evaluation (as of July 31st, 2014)

Current R&D and Innovation Portfolio leveraging collaborative R&D

ILI, $14.7M, 46%
Other, $8.8M, 27%
Integrity, $8.7M, 27%

TOTAL: $32M for $4.8M PG&E funding
R&D and Innovation Connection

Natural Gas Industry
R&D and Innovation
In Line Inspection
Explorer Robotic Tools

- Non-tethered, battery-powered in-line inspection robotic tools for unpiggable transmission pipelines.

- Key Features:
  - Launch and receive through pressure control fitting via hot tap (traditional pig launcher and receiver not required)
  - Navigates through “unpiggable” features:
    - Mitered and < 1.5D radius bends
    - Plug valves
    - Low pressure and flow conditions
  - Performs NDE (Non Destructive Evaluation) and visual inspection (2 high resolution cameras) for metal loss, cracks, and mechanical damage.
Explorer Sensors & Technologies

**Mechanical Damage Sensor**
Laser-based sensor detects and measures mechanical damage and ovality

**In-Line Charging Tool**
Charges batteries of Explorer tools through a hot tap to extend range of inspection.

**Rescue Tool**

**Crack Sensor**
Combination of Electromagnetic Acoustic Transducer (EMAT) and Transverse MFL to detect cracks (in development)

**Pipeline Cleaning Tool**

**Sharp Bend Inspection**
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.
Diakont Girth Weld Scanner

- Multi-channel Electro-Magnetic Acoustic Transducer (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 at PG&E’s Applied Technology Services (ATS) laboratory and then, on new girth welds on L-132 replacement sections in South San Francisco in September 2014.
- Results will help:
  - Assess girth weld integrity for construction defects especially in condition of underground movements
  - Replace UT based techniques that require water coupling
Improving MFL Storage Well Casing Assessments

- 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

Example of Geo-mechanical Loads on Downhole Pipe
Robot for Visual Inspection of Pipe Casing through Vents

- NYSEARCH project with Honeybee Robotics initiated in 2012.
- 2” tall robotic tool can enter pipe casing through vents. Excavating for casing end seal access not needed.
- Performs visual inspection of external surface of carrier pipe and pipe casing using cameras.
- Can aid in prioritization of ILI inspection and digs
- First functional prototype tested by National Grid in February 2013
- Second prototype tested at National Grid in July. Second demonstration to be held at PG&E in September 2014.
Integrity Management
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
Joint Industry Project with 15 operators, led by DNV, to investigate the use of hardness testing to estimate yield strength of steel pipelines (API 5L, Grade B through X52).

Results can help with determination and validation of MAOP and avoid pressure reductions.

Common in-the-field hardness testers (Telebrineller, UCI, and Leeb Ball Rebound) evaluated against metallurgical characterization and tensile testing to validate approach.

All instruments provided conservative estimates of YS compared to actual YS.
Currently PG&E’s model assigns a relative score for each threat for each segment of the Transmission system.

To represent that threats may interact and increase risk, a model based on failure data has been developed by Kiefner with NYSEARCH.

Easy to import in existing model.

Set of coefficients that represent the increased likelihood of failure (LOF) due to threat interactions.
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.)
Acellent RAPID System

- Demonstration of technology developed by Acellent Technologies, funded through CEC-PIER program.
- The Real-time Active Pipeline Integrity Detection (RAPID) system is a distributed piezoelectric sensor network adhered to the pipe surface.
- Currently testing ability of technology to perform in-situ Structural Health Monitoring of metal loss defects and provide early indication of damage.
- Demonstration held at ATS in June on 12” test loop
- Obtaining input from PG&E SMEs on defect parameters (internal/external corrosion, erosion, gouges, etc.) for the current blind testing phase.
First developed for the dental industry, as a spin-off from University of Kentucky, the 3D Toolbox was detected by PRCI through the NASA Tecfusion program.

Used like a digital camera, 3D Toolbox captures 3D image of pipe surfaces and provides measurements and analysis of the surface condition.

PG&E verified the tool performance through a series of lab and field tests and is in the final stages of its deployment.
CIP – Dent Validation

- Collaborative Industry Project (CIP) funded by several oil and gas operators, led by Stress Engineering Services
- Objective is to perform dent severity analysis using ILI caliper sensor data
- Will build upon the Fitness For Service evaluation per API 579 and add full-scale pressure testing on a re-created sample, and repair solution if needed
- PG&E’s focus will be on unconstrained dents on 12” and 18” diameter pipelines
- Project to be completed by 4Q 2014

Full-scale Indenter at Stress Engineering Services

Stress Contour Plots from Finite Element Analysis of Sample Dent
NDE for Polyethylene Butt Fusion Joints

- 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

Prototype of NDE system for Butt Fusion joints in PE pipes
(Ref.: TWI WINDEPP Program)
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.
The handheld methane detector utilizes the same laser based technology that NASA has installed on its planetary rovers to detect methane on Mars.

The tool has superior sensitivity (parts per billion) compared to other commercial handheld detectors. It is also lightweight (250g).

When completed, the tool is expected to reduce time taken to locate leak in association with vehicle based survey.
JPL lightweight methane detector mounted on a small drone to detect methane and locate leak.

- Mandate to the FAA for regulation of commercial applications of drones in September 2015.
- Totally automated drone that can be launched by utility crew in the field to survey portions of pipeline and locate leaks.
Stationary Methane Laser Sensor

- 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.
Damage Prevention
### Objectives

- **Detect Construction Equipment/Activity**
- **Eliminate False Alarms**
- **Locate Construction Equipment**
- **Control HDD**
- **Locate Pipelines**
- **Improve Communication**

### Needs and Gaps

- **Satellite Observation**
- **Aerial Surveys - Drones**
- **Image Analysis**
- **Optic Fiber (Cost Reduction)**
- **Ground Acoustic Sensors**
- **Signal Analysis**
- **Video Surveillance**
- **Electronic Fence**
- **Multiple Signal Analysis**
- **GPS Localization**
- **Best Practices**
- **XYZ localization sensor**
- **GIS location validation**
- **Ground Penetrating Radar**
- **Acoustic sensor**
- **RFID markers**
- **Smart Phone Solutions**
- **Standardization**

### R&D Projects and Technologies

<table>
<thead>
<tr>
<th>Year</th>
<th>Satellite Observation</th>
<th>Aerial Surveys - Drones</th>
<th>Image Analysis</th>
<th>Optic Fiber (Cost Reduction)</th>
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<th>Acoustic sensor</th>
<th>RFID markers</th>
<th>Smart Phone Solutions</th>
<th>Standardization</th>
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### Time Line

- <2012
- 2012
- 2013
- 2014
- 2015
- >2015

### Road Maps

- **Road Maps Overview**
- **Prevent 3rd Party Damage**
- **Damage Prevention**
- **Objectives**
- **Needs and Gaps**
- **R&D Projects and Technologies**
- **Deploy**
- **Design**
- **Test**
- **Develop**

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**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
- Solution expected to be cheaper and more effective than ultra-sonic and fiber optic detection systems
- First field tests performed at PG&E in August 2014.
RFID to mark plastic pipes and assure material traceability

- RFID is used to precisely locate the pipe with active antenna.
- Precision is x-y: 1”, z:4” down to 5’.
- Additional information about the pipe is recorded in the RFID following ASTM standard to assure material traceability.
- Developed in Europe. First field tests performed at PG&E in June 2014.
- Pipe embedded version expected for the end of 2014.
Excavation and Construction Technologies
Automated Welder for Laterals

- 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

Prototype of Automated Welding Unit
(Ref: GTI, Dennis Jarneck)
Polyethylene Pipe Splitting Tool Development

- 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.

Mini-GRUNDOTUGGER from TT Technologies
Composite Repair on Polyethylene Pipe

- 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

Composite repair trial on polyethylene pipe.

Hydrostatic pressure test on repaired sample; failure outside of repair area.
Remote QA/QC Process

- 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.
Self-Healing Material and Pipe Development

- 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

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

- Innovation is key for improving pipeline safety at a reasonable cost

- Two strategies to succeed:
  - Align efforts internally, communicate and build connections with the operation teams
  - Collaborate with others externally
    - Leverage additional resources
    - In safety, no point to be the only one who is right
    - Create a broader market for our vendors

- Already some success stories and lot in the work

- Deployment of new solutions is our goal
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Our Tool Box
### Project Assessment and Support Sheet

<table>
<thead>
<tr>
<th>Strategy</th>
<th>Innovation</th>
<th>Leverage</th>
</tr>
</thead>
<tbody>
<tr>
<td>What issue(s) does it solve?</td>
<td>What is the state of the art?</td>
<td>How does the project leverage previous work?</td>
</tr>
<tr>
<td>How does it fit in our overall strategy and rank among our priorities?</td>
<td>What is the existing solution at PG&amp;E?</td>
<td>What are the opportunities of co-financing?</td>
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<tr>
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<td>How does the team compare to competition?</td>
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</table>

#### 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?
## Developing a Network of Innovation Champions within Gas Operations

### Assignment Options:

- **RDI Fellow**
  - 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

- **RDI Senior**
  - 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

- **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

### Orientation Presentation

- 5+ year
  - 5% Part time assignment
  - RDI Fellow
- 2-4 year
  - 5% Part time assignment
  - RDI Senior
- 0-1 year
  - 2 – 6 month part time assignment
  - RDI Associate
Fostering Innovation

Internally

Idea Box
- Web page
- Short Description and Contacts
- Solutions and Issues
- Support to form the ideas

Externally

Scouting for Solutions
- ORACLE (NYSEARCH)
- TECHFUSION (NASA)
- Others...

Harvesting

Centralized Information

Catalyzing

Focus Groups
- Creativity Sessions at Team’s requests
- Facilitated sessions

Innovation Competitions
- Invite innovators to present to clients
- Jury elects best solutions
- Commitment to support development and tests
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

![Diagram showing the relationship between Technology and Business with quadrants labeled Semi-Radical, Radical, Incremental, and Semi-Radical.]

Operationalize Deployment