In-Space Inspection Workshop
Bridging the Gap between the Aerospace and Petro-Chemical Industries

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Petrochemicals significantly impact the economic growth and development of the U.S. and world economies.

Hence, the importance of value addition in the oil, gas and petrochemicals market is higher than in any other industrial sector.

490 million tons of petrochemicals are used annually across all sectors; primarily construction, agriculture, packaging, automotive and electrical & electronics industries. The rise in the petrochemical market is expected to reach $758.3 Billion by 2022.
Crude oil price had been on the rise since 2004 and traded for nearly $139 per barrel at its peak in mid-2008. However by midyear 2014, prices began to slowly collapse from over $105 per barrel to below $50 per barrel by January 2015.

Vertical hydraulic fracturing ("fracking") and horizontal drilling in multistage hydraulic fracturing resulted in a considerable rise in natural gas production in the United States. Other countries are reexamining their natural gas reserves and pursue development of their own gas plays.

Shale gas evolution in North America is likely to change the dynamics of the global petrochemicals industry by 2020.
Increasing concerns over fossil fuel supply and consumption, with respect to their impact on health and the environment, have led to the passage of legislation globally.
The petrochemical industry culture

2015 Lloyd’s Register Industry Survey of petrochemical company executives

• 67% say that in a low-price environment ($50-$60/barrel)
• Data collection and analytics will be important to their innovation efforts over the next two years

The primary drivers of innovation investment are:

• 36% Reducing costs
• 46% Improving operational efficiency
• 56% say data collection and analytics will be important to their innovation efforts over the next two years
• 35% Improving access to potential reserves
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How successful has your organisation been at meeting its innovation goals and objectives over the last two years?

44%  
Highly unsuccessful – we’ve fallen short on all of our innovation goals/objectives

35%  
Highly successful - we’ve met, or exceeded, all of our innovation goals

13%
The petrochemical industry culture

• 70% say the challenges involved with the real-world deployment of new technologies is a key barrier to innovation
• 70% Bringing new technologies or other innovations to market is taking far too long
• (42%) say their firms need to create a "culture of innovation".
• 76% Say oil price instability has led them to slow down or halt most innovation initiatives
• Deployment of new technologies remains a major innovation challenge:
  • “Most of what we're embracing in data capabilities are coming from outside, developed for other industries. There are fantastic companies and universities who have data analytics that are opening our eyes to what might be possible."
The petrochemical industry culture

- A majority of Petrochemical executives report that:
- They are under pressure to collaborate with organizations both inside and outside the oil and gas sector.
- The barriers to genuine collaboration in innovation, especially among operating companies, remain formidable.
- A long and thoroughgoing shift in culture is required for collaborative innovation to become the norm in upstream oil and gas.
The pressure to collaborate with firms outside the oil and gas industry is fueling an interest in crossover technologies to improve performance in surveying, modelling, drilling, monitoring and other areas.

In addition to aerospace and defense, operating companies’ technology teams are also scoping opportunities originating from the automotive, IT, telecoms and biomedical sectors.

By executives’ own admission, however, they are not outstanding in their use of the data they generate. Two factors stand out as hindrances to the better use of data: silos and data relevance and integrity.

According to Nathan Meehan, President of the Society of Petroleum Engineers, companies are concentrating on projects that have a good chance of succeeding in the near term. “They may be in material science or efficiency improvements, or displacement of other technologies. However long-term, disruptive innovation projects are going to take a back seat for now,” he says.
• What level of collaboration exists between segments in the NDT industry? Petrochemicals, aerospace, medical, power generation, manufacturing, marine, etc.
• Does collaboration occur at the right levels?
• Which organizations are willing to foster cross-segment or cross-industry collaboration?
  • ASNT, NASA, API, EPRI, ASME, PRCI, AWS, PCN?
• What would effective collaboration look like?
• What would be some examples?
Composite Pipe

- Carbon fiber piping for subsea oil and gas production
- Does not corrode
- High resistance to erosion
- Low thermal expansion
- High resistance to fatigue
- 10X cost of carbon steel pipe
- Limited inspection method options
- Not cost effective for reducing offshore production
- Where is the bar for buy in by offshore producers?
The cost of offshore operations must be reduced!

• Offshore oil production can cost between $55-84/barrel

• The number of operations and regular offshore personnel are to be minimized or eliminated through autonomous topside and subsea systems (unmanned platforms)
• Oil companies are looking for game changing technologies that will keep offshore production competitive

• Low oil prices not only reduce budgets, they significantly raise the bar for project approvals

• A proposed non-intrusive robotic inspection system may save $100K per vessel entry avoided, however projects with a cost savings of $100M or more are being sought

• What about robotic technologies?
Pressure Vessel Design Components

- Lifting lug (External feature)
- Nozzle weld (T-weld)
- Set on Nozzle
- External stiffener (External feature)
- Seam weld (Butt weld)
- Girth weld (Butt weld)
- Dome - Spherical shell (Shell)
- Cylindrical shell (Shell)
- Weir plate (Internal feature)
- Saddle plate (External feature)
Wide Range of Topside and Subsea Piping Configurations

Small Bore Branch Piping

Subsea Wet Insulation
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Robotic Subsea Pipe Inspection

External ROV Deployable Robots: Remote Video, Ultrasonics, Digital Radiography, Electromagnetics

Internal Inspection Robotics: In-Line Inspection Tools: Ultrasonics, Electromagnetics, Laser Profile, Tethered, Free Swimming
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Permanently Installed Sensors (PIMS)

High density Ultrasonic Sensor Grid
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Pipe Screening Techniques

ROV Deployed Long Range Guided Wave UT

Pipe Wall Loss Screening: Semi-Quantitative
Robotic Crawlers

Self-Propelled or Tethered Unpiggable Pipeline Inspection Robot: Remote Visual, Laser Imaging, Ultrasonics

Requires Open Access
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Robotic Crawlers for Internal Repairs

Internal Grinding Crawler

Removing Internal Metal
Robotic Crawlers for Installed Corrosion Resistant Coatings

Internal Coating Robot

Installed Corrosion Resistant Coating
Articulating Robotic Cleaning and Inspection Arm

Introduced through a pressure vessel manway and operated for wide area access
Miniature robotic inspection systems are typically used for internal inspection of piping, pressure vessels and storage tanks.

- They may use crawlers, tethers or flow induced motion.
- They typically inspect a greater range of component sizes, geometries and accessibility.
- Each machine is typically limited to one or two inspection methods.

Miniature RVI of a pipe in pipe annulus.
Subsea System Delivery, Maintenance and Communications

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Miniature, self-propelled subsea inspection robot

On-Station Programmable AUV

Autonomous Surface Vehicle

Potential to Deploy Miniature, Self-Propelled Robots
Long-Term Thinking
Robot Scale and Adaptability

- **Nanorobots** (nanobots or nanoids) are typically devices ranging in size from 0.1-10 micrometers and constructed of nanoscale or molecular components.

- Commercial viability estimated within 10 years
The Case for Nanorobots

• Nanorobotic devices will be used to protect the human body against pathogens

• Nanocomposites: Carbon will be a primary material of construction due to its strength and chemical inertness.

• Nanorobots will contain electric circuitry and sensors as well as mechanized control surfaces such as propellers, fins and functional appendages

Robot size = 0.1-10 micrometers
Nano robots

• May be introduced directly into process streams
• May be programmed to collect data and perform specific tasks
• May be able to withstand and react to harsh environments
• May be harvested from the process stream for data retrieval and analysis

Key question: Could Nanorobots be used aid in corrosion resistant or self-healing materials?

Robot size = 0.1-10 micrometers
Nanorobots

- Self-Replication: Nanorobots might be able to reproduce themselves in order to remain operational for years.
Nanorobots
Self-reconfiguring modular robots
• Can make a range of complex machines out of a single (or relatively few) types of mass produced modules
• Reconfiguration ability allows a robot or group of robots to disassemble and reassemble to form new morphologies that are better suitable to new tasks
Nanorobots

Swarm robotics

• Following simple programmed rules, autonomous robots arrange themselves into vast, complex shapes
Questions for Discussion

• Could Nanorobots be the $100M prize by their ability to reduce, trigger or in some cases eliminate the need for internal inspections with high data confidence?

• Could Nanorobots be programmed to perform on-stream inspection tasks?

• Could they store energy or draw the energy required to perform their tasks from a process stream?

• Could they be programmed to respond to material damage wherever it occurs and record its position and severity?
Questions for Discussion

Chemical injection programs:

• Oil companies spend $millions on production chemicals per year
• The intent is to use enough chemicals to reduce or eliminate microbiological species throughout the volume of the process stream that may cause (MIC) corrosion
• Could Nanorobots be programmed, (similar to the goal of the medical industry) to identify and destroy specific MIC species that attach themselves to the inner walls of process equipment?
• Could spent Nanorobots be harvested and reused?
Questions for Discussion

Isolated Wall Loss Damage Detection and Prevention:

• The medical industry is working on Nanorobots that can send and receive ultrasonic “pings”

• Industrial Ultrasonics currently uses spaced sensors to pitch/catch ultrasonic pulses in order to establish small, localized wall loss features between each sensor

• Could Nanorobots be programmed to attach and array onto internal process walls in order to detect local wall loss?

• Could the detection of localized wall loss trigger programmed responses such as the production and use of MIC prevention or other Nanorobots? Modified replications, reconfiguring or swarm?
Questions?
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Thank You!

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