REX2019

PRCI RESEARCH EXCHANGE

REX 2019

PROGRAM GUIDE, AGENDA & ABSTRACTS

WELCOME TO THE 2019 PRCI RESEARCH EXCHANGE MEETING!

We are pleased to welcome you to our 13th annual Research Exchange Meeting! This meeting is scheduled each year to provide PRCI member companies, our key research partners, and external stakeholders with a report on important research results and provide a forum for an exchange of ideas. This event is the key knowledge transfer window for PRCI and will provide the attendees an opportunity to learn how to move the results into practice.

REX2019 will include two days of presentations on Tuesday & Wednesday, covering a variety of safety and integrity management topics, including but not limited to corrosion assessment; addressing cracks & dents; right of way monitoring; design considerations; material characteristics and properties; in-line inspection performance and enhancement; NDE technology enhancements and validation; leak detection; welding; human factors; and subsea research. The event will host a special workshop on the development of a Pipeline Datahub for the industry. In addition to the technical presentations, there will be networking opportunities and receptions for attendees to engage with industry colleagues.

Following the Research Exchange Meeting, each of the Pipeline Technical Committees: 1) Corrosion, 2) Design, Materials & Construction (DMC), 3) Inspection & Integrity (I&I), 4) Subsea, and 5) Surveillance, Operations & Monitoring (SOM) will meet on Thursday and Friday for a working session. The Technical Committee meetings are limited to PRCI members and invited guests only.

On-site Registration

The registration desk will be open throughout the duration of the meeting. When you arrive for the meeting, please proceed to the registration desk to pick up your name badge. **It is very important that you wear your name badge AT ALL TIMES throughout the conference.** This will be your pass to gain admittance to the various sessions, breaks and meals. At the end of the conference, before leaving, we ask that you return your name badge to the registration desk so they may be recycled.

Registration Desk Location & Hours:

The registration area will be located in the prefunction area outside the Legends Ballroom on the Lobby Level of the hotel (see floor plan):

- Tuesday, March 5 | 7:00am – 5:00pm
- Wednesday, March 6 | 7:00am – 5:00pm
- Thursday, March 7 | 7:30am – 5:00pm
- Friday, March 8 | 7:30am – 12:00pm

Complimentary Internet Access

Your meeting registration includes complimentary internet access during the meeting sessions. You may access it with the following credentials:

Network: Sonesta Guest
Access Code: PRCI2019

1. Enable Wi-Fi on Your Device
2. Please Select the "Sonesta Guest" Network
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4. Scroll Down and Click on the "Passcode" Option
5. Type in "**PRCI2019**" for Complimentary Internet Access.

Follow Us on LinkedIn!

Show your support of PRCI by following us on LinkedIn! Share a PRCI post by the end of the meeting to be entered for a chance to win a $100 VISA gift card!

Parking & Transportation

Your meeting registration includes complimentary parking in the hotel's garage for daytime parking and a 50% discount for overnight parking. Please visit the registration desk to pick up a parking voucher to use when you exit the garage.

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2222 West Loop South
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George Bush Intercontinental Airport (IAH)
Distance: 28 MI / 45.06 KM North to Hotel
SuperShuttle Charge
Take Beltway 8 West to Interstate 45 South. Exit 610 West and continue on to 610 South. Exit San Felipe. Go through the light and the Royal Sonesta Hotel Houston will be on the right side of the street.

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Distance: 16 MI / 25.75 KM South East to the hotel
SuperShuttle Charge

Take Interstate 45 North to 610 Loop West, continuing to 610 Loop North. Exit at San Felipe. U-turn at the light and the hotel is located between San Felipe and Westheimer Road.

Professional Development Hours

Attendance at the PRCI Research Exchange Meeting qualifies as an opportunity for Professional Engineers to earn Professional Development Hours (PDH). Certificates of attendance will be emailed to you after the meetings. Please be sure to pick up your name badge at the registration desk and sign the sign-in sheet for each of the sessions you participate in to confirm your attendance. If you do not pick up your name badge, we will assume you did not attend the meeting and will not receive a certificate.

Sponsors

We would like to thank our sponsors for their generous contributions to facilitate the presentation of important research results and outcomes for PRCI research projects and programs, as well as other conference functions.

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2019 PRCI RESEARCH EXCHANGE MEETING

Royal Sonesta Hotel Houston Galleria | 2222 West Loop South | Houston, Texas 77027 | +1 (713) 627-7600
March 5-6, 2019

Agenda

Tuesday, March 5, 2019

7:30 AM to 8:00 AM	**BREAKFAST & REGISTRATION | LEGENDS PREFUNCTION AREA, Lobby Level**	
8:00 AM to 9:00 AM	**OPENING PLENARY SESSION | LEGENDS 4-7, Lobby Level** Opening Remarks: Cliff Johnson, President of PRCI Keynote Speaker: Thornton May, Futurist & Author – "Data about Data: Mapping the Future of Knowing" Presentation of Distinguished Service Awards, In-kind Support Awards, and Distinguished Researcher Awards	
9:00 AM to 9:30 AM	**BREAK | LEGENDS PREFUNCTION AREA, Lobby Level**	
9:30 AM to 12:00 PM	**TRACK ONE: CORROSION** LEGENDS 4-7, Lobby Level	**TRACK TWO: LEAK DETECTION & RIGHT OF WAY** LEGENDS 1-3, Lobby Level
	9:30 AM Plausible Profiles (Psqr) Corrosion Assessment Model-Refinement and Further Validation *Shahani Kariyawasam, TransCanada*	9:30 AM Application of Machine Learning to Improve Lead Detection Capabilities of Distributed Temperature Sensing (DTS) Systems *Maria Araujo, Southwest Research Institute*
	10:00 AM Investigation of Biomethane Trace Elements Composition: A Tool to Better Know the Composition of the Gas Injected *Amelie Louvat, RICE GRTgaz*	10:00 AM SmartBall Technology: An Innovative Multi-sensor Tool for Long Inspection of Oil and Gas Pipelines *Carine Lacroix, GRTgaz - RICE*
	10:30 AM An Alternative Approach to the Assessment of Corrosion Anomalies within Pipelines *Ryan O'Kelley, Atteris LLC*	10:30 AM Autonomous Aerial Detection of Liquid Hydrocarbons Leaks in Water Bodies *Maria Araujo, Southwest Research Institute*
	11:00 AM Microchemical, Chemical, and Corrosion Samples *Mohita Sharma, University of Calgary*	11:00 AM Pipeline Leak Rate Estimation *Mark Piazza, Colonial Pipeline Company*
		11:30 AM Visualizing Buried Networks in Augmented Reality *Carine Lacroix, GRTgaz - RICE*
12:00 PM to 1:00 PM	**LUNCH | DISCOVERY CENTER, Lobby Level**	
1:00 PM to 3:00 PM	**TRACK ONE: CORROSION** LEGENDS 4-7, Lobby Level	**TRACK TWO: LEAK DETECTION & RIGHT OF WAY** LEGENDS 1-3, Lobby Level
	1:00 PM Clearing of Shorted Casings vs ILI Based Management – A Data Driven Approach to Preventing Failures and Managing Risk *Shahani Kariyawasam, TransCanada*	1:00 PM CONOPs for LiDAR Operationalization for ROW Monitoring *Francois Rongere, PG&E*
	1:30 PM Proposal of New HIC Test Solution with Good pH Stability for Fitness for Purpose Evaluation *Daisuke Mizuno, JFE Steel Corporation*	1:30 PM Evaluation of Current ROW Threat Monitoring, Application, and Analysis Technology Project Update *Paul Adlakha, LOOKNorth, C-CORE*
		2:00 PM Obstacle Detecting Technology for Horizontal Drilling *Carine Lacroix, GRTgaz - RICE*
		2:30 PM Remote Monitoring of Geohazards for 800+ Kilometers of Pipeline and Right-of-Way Protection in Permafrost, Snow and Vegetation Using Radar Satellite Interferometry (InSAR) *Kris Covey, 3vGeomatics Inc. & Shin-ichi Sobue, Japan Aerospace Exploration Agency (JAXA)*
3:00 PM to 3:30 PM	**BREAK | LEGENDS PREFUNCTION AREA, Lobby Level**	
3:30 PM to 5:00 PM	**PIPELINE DATA HUB - GENERAL SESSION | LEGENDS 4-7, Lobby Level** Chairs: Walter Kresic, Enbridge and Cliff Johnson, PRCI Panelists: Sean Keane, Enbridge; Shahani Kariyawasam, TransCanada; and Jim Andrew, Flint Hills Resources; Gary Hines, PRCI	
5:00 PM to 6:30 PM	**RECEPTION | DISCOVERY CENTER, Lobby Level** Come and join PRCI members for an evening of drinks, hors d'oeuvres and networking.	

2019 PRCI RESEARCH EXCHANGE MEETING

Royal Sonesta Hotel Houston Galleria | 2222 West Loop South | Houston, Texas 77027 | +1 (713) 627-7600
March 5-6, 2019

Agenda

Wednesday, March 6, 2019

7:30 AM to 8:00 AM	**BREAKFAST & REGISTRATION | LEGENDS PREFUNCTION AREA, Lobby Level**			
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	8:30 AM	Full Scale Cyclic Fatigue Testing of Crack-in-Dent and Development of Frame Work for Life Prediction *Udayasankar Arumugam, Blade Energy Partners, Ltd.*	8:30 AM	Mechanical Properties of Vintage Girth Welds and Their Implications on Performance *Dan Jia, CRES*
	9:00 AM	Towards a Reliability-Based System-Wide Integrity Management Approach for Pipeline Dents *Nader Yoosef-Ghodsi, Enbridge*	9:00 AM	Fracture Resistance Testing of Dissimilar Girth Welds Using SE(T) Specimens *Eduardo Hippert, Petrobras and Claudio Ruggieri University of São Paulo, Brazil*
	9:30 AM	Leveraging Industry Data Sharing to Support Improved Crack Management Programs at a Liquids Operator *Steven Bott, Enbridge Liquids Pipelines*	9:30 AM	Tensile Strain Capacity of Girth Welds *Bo Wang, CRES*
10:00 AM to 10:30 AM	**BREAK | LEGENDS PREFUNCTION AREA, Lobby Level**			
10:30 AM to 1:00 PM	**TRACK ONE: IN-LINE INSPECTION & NONDESTRUCTIVE EXAMINATION** LEGENDS 4-7, Lobby Level		**TRACK TWO: DESIGN, MATERIALS & CONSTRUCTION** LEGENDS 1-3, Lobby Level	
	10:30 AM	A Comprehensive Assessment of Inspection Technologies for Characterizing ERW Seam Anomalies and Impact on Pipeline Integrity Management *Mark Piazza, Colonial Pipeline Company*	10:30 AM	Significance of Automatic Pipe Dimension Measurement of Line Pipe for Deep Offshore Pipe Lines ***(moved from Subsea track)*** *T.S Kathayat, Welspun*
			11:00 AM	EPRG Approach to Assess Avoidance of Brittle Fracture in Presence of Ductile Initiation in DWT Tests *Marion Erdelen-Peppler, European Pipeline Research Group*
	11:30 AM	A Novel Method in Assessment of Corroded Steel Pipe in Water Lines Ali Alavinasab, Xylem	11:30 AM	Evaluation of Cracked In-service Welded 4" Stub End with LOR Flange *Otto Jan Huising, N.V. Nederlandse Gasunie*
	12:00 PM	Evaluating SCC in Pipelines with IWEX Harvey Haines, Applus RTD & Ben Hanson, Kinder Morgan	12:00 PM	Soil-pipe Interaction in Muskeg Soils for Design of Buried Energy Pipelines *Dharma Wijewickreme, University of British Columbia*
	12:30 PM	MAOP Verification of Facility Piping Peter Veloo, Exponent and Michael Rosenfeld, Kiefner & Associates	12:30 PM	Composite Crack Reinforcement *Chris Alexander, ADV Integrity, Inc.*
1:00 PM to 2:00 PM	**LUNCH | DISCOVERY CENTER, Lobby Level**			
2:00 PM to 4:00 PM	**TRACK ONE: SAFETY MANAGEMENT** LEGENDS 4-7, Lobby Level		**TRACK TWO: SUBSEA** LEGENDS 1-3, Lobby Level	
	2:00 PM	NDE - Technician Qualification - Industry Improvement Efforts *Michael Sens, Chevron & Andri Orphanides, API*	2:00 PM	Local Hard Zone Formation in Sour Service Pipeline Steels *Douglas P. Fairchild, ExxonMobil Upstream Engineering*
			2:30 PM	Flexible Riser Life Extension using Advanced inspection and Analysis *Arya Majed, INTECSEA*
	3:00 PM	Determining the Impact of Human Factors on the Performance of In-Service NDE *Jane Rau, Jtrain*	3:00 PM	Validation of an Ultrasonic Phased Array Tool for Inspection of Weld Overlay Cladding for Subsea Applications *Channa Nageswaran, TWI Ltd.*
	3:30 PM	Competency in the Pipeline Industry: An Industry Survey *Reena Saheny, PBOK*		

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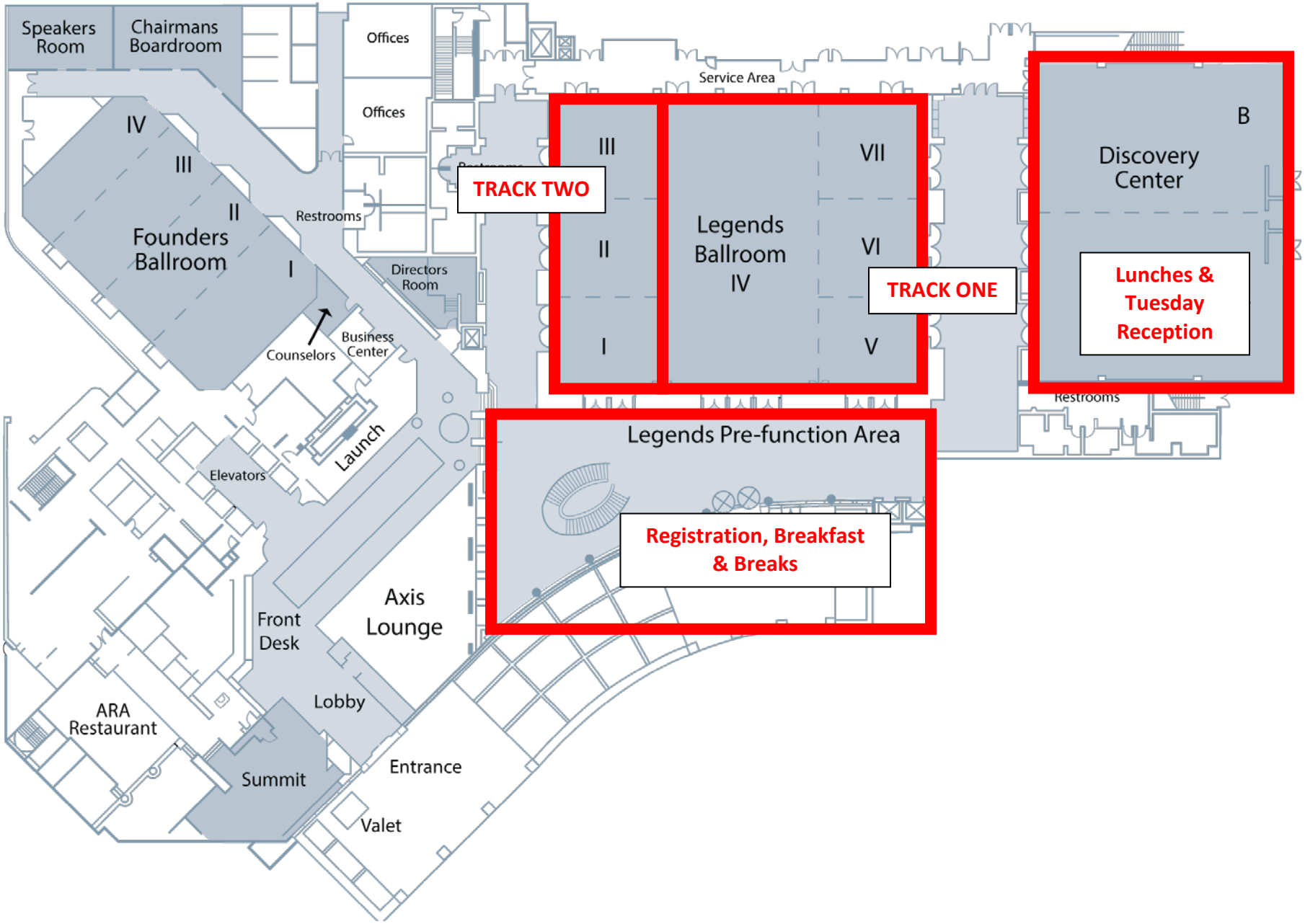

Keynote Speaker: Thornton A. May, Futurist, Author and Education, Co-Founder, The Digital Value Institute
Data about Data: Mapping the Future of Knowing

"They couldn't hit an elephant at this dist…," were the last words of Union Army General John B. Sedgwick at the Battle of Spotsylvania in 1864. He died of a lack of technology imagination (failure to understand what technology can do to you or for you). No one attending Thornton's keynote is going to suffer this fate.

Every day, every one of the 86,300 drivers at UPS is confronted with an enterprise performance impacting choice – what route do they drive? This is a bigger cognitive deal than many might imagine. There are more ways to deliver a UPS route than there are nanoseconds in the Earth's existence. Every day, every pipeline professional is confronted with potentially career-trajectory and industry-reputation-impacting choices. What role will data, analytics, machine learning and artificial intelligence play in your future?

Strategists at Houston Methodist hypothesize that we are less than five years away from a time when doing radiology without an A.I. assist will be considered malpractice. Are similar trends at work in our industry?

Futurist Thornton May via a highly interactive session will share results of a six year, seven university, six hundred organization study of with-data value creation.

Participants will emerge from this two-day intensely interactive session with:

- Self-Knowledge
- Other Knowledge - How others are thinking
- Environmental Knowledge - What is really happening in the data world today
- Movement Knowledge - What are the change vectors
- Value Knowledge - Where money/mission value can be delivered

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Thornton May is a futurist, educator, anthropologist and author. His extensive experience researching and consulting on the role and behaviors of "C" level executives in creating value with information technology has won him an unquestioned place on the short list of serious thinkers on this topic.

Thornton combines a scholar's patience for empirical research, a stand-up comic's capacity for pattern recognition and a second-to-none gift for storytelling to address the information technology management problems facing executives.

The editors at eWeek honored Thornton, including him on their list of "Top 100 Most Influential People in IT." The editors at Fast Company labeled him one of the "Top 50 brains in business." Thornton May is also the author of The New Know: Innovation Powered by Analytics.

Thornton May has established a reputation for innovation in time-compressed, collaborative problem solving. He designs the curriculum that enables the mental models which allow organizations to outperform competitors, delight customers and extract maximum value from tools and suppliers.

Thornton's insights have appeared in the Harvard Business Review (on IT strategy); The Financial Times (on IT value creation); The Wall Street Journal (on the future of the computer industry); the M.I.T. Sloan Management Review (on the future of marketing), American Demographics (on the evolving demographics of Electronic Commerce), USA Today (on the future of the consumer electronics industry) Business Week (on the future of CEO direct reports), and on National Public Radio (debating the future practice of strategy with Professor Michael Porter). Thornton is a columnist at Computerworld and has served as an Advisor to the Founding Editors of Fast Company Magazine.

Thornton's research has been acknowledged in such seminal business books as Seth Godin's Permission Marketing; Michael Schrage's Serious Play: How the World's Best Companies Simulate to Innovate; Moshe Rubenstein's The Minding Organization; Bill Jensen's Simplicity; and Jeff William's Renewable Advantage: Crafting Strategy Through Economic Time.

2019 PRCI Research Exchange Meeting

March 5-6, 2019 | Houston, Texas
General Session Abstracts

Tuesday, March 5, 2019 – PIPELINE DATA HUB SESSION

3:30 PM – Pipeline Data Hub Session

Chairs: Walter Kresic, Enbridge Pipelines & Cliff Johnson, PRCI
Speakers: Gary Hines, PRCI; Shahani Kariyawasam, TransCanada; Jim Andrew, Flint Hill Resources; Sean Kean, Enbridge

At the 2018 Research Exchange Meeting PRCI introduced the concepts behind the Pipeline Data Hub (PDH) and explored how the Aviation industry had successfully used a similar model to enhance aviation safety. The PDH is an opportunity for PRCI, its members, and the industry-at-large to leverage our long history of data sharing as a tool to enhance pipeline safety and integrity.

There is a vast untapped information pool within the pipeline industry that is awaiting a broad industry coordination effort in order to extract and use. Being at the forefront of our industry, it is both a need and an opportunity for PRCI to establish a deeper competency regarding data mining and analytics, and to be a coordinator of data sharing. The data science path for PRCI will aim on being a center for collective information in support of the R&D mandate.

The forum will provide an update on the development of the PDH, an update on the Pipeline Hazardous Materials Safety Administration Voluntary Information Sharing effort, and three case stories on how data is being used by pipeline operators.

Agenda:

- Introduction and overview – Walter Kresic, Enbridge Pipelines & Cliff Johnson, PRCI
- PHSMA VIS Update – Gary Hines, PRCI
- Sharing Model Performance Data Towards Collective Intelligence – Shahani Kariyawasam, TransCanada
- Moving from Company Knowledge to Industry Knowledge – Jim Andrew, Flint Hill Resources
- Using Data to Make the Work a Better Place: Back to the Future – Sean Keane, Enbridge

Tuesday, March 5, 2019 – TRACK ONE: CORROSION

9:30 AM – Plausible Profiles (Psqr) Corrosion Assessment Model-Refinement and Further Validation

Presenter: Shahani Kariyawasam, TransCanada

Value to Operators: Metal-loss corrosion is one of the major threats to structural integrity of oil and gas pipeline system. The assessment model plays a critical role and has significant impact on the integrity decisions for corrosion assessment. Use of one existing model over another can significantly change the number ensuing activities, such as excavations based on the ILI, by one or two orders of magnitude. By improving the accuracy and precision in the assessment model safety can be maintained while reducing unnecessary activities.

The use of Psqr model brings significant cost savings (up to 80% reduction in excavations and repairs on pipelines with wide corrosion), which has been demonstrated by the case studies. It is estimated to save the company around 15 million per year.

TransCanada is currently working with PRCI to establish the model as a mainstream methodology for the industry. Other operators could also benefit similarly by using the Psqr model for ILI based excavation decisions, repair decisions, and derate calculations. The impact to these decisions is documented in this research.

Description of the research: The corrosion assessment model is used to make many integrity decisions including, but not limited to:

- Identifying features that need excavation based on ILI-reported sizing.
- Calculating the derate pressures
- Making repair decisions in the ditch

Based on TransCanada's reliability program, it was identified that decision making is most sensitive to the accuracy and precision of the assessment model. A more accurate model makes both the probabilistic and deterministic assessment less conservative without compromising safety. A new assessment model, called plausible profiles (or Psqr) model, was developed by TransCanada in 2016. The model was first validated using 14 full-scale burst tests, and has been presented to the PRCI TC meeting in October, 2017 and PRCI research exchange meeting in March, 2018. To refine the assumptions and further validate the model, a total of 16 full-scale burst tests were completed in 2018. The validation has demonstrated that the Psqr model is more accurate and more precise than the RSTRENG model. The sensitivity analyses of model parameters have been rigorously examined, and has verified the model is safe. Some parameters of the model were adjusted to consider some extreme morphologies. The Psqr model will be the basis for the refinement of integrity decisions mentioned above so that unnecessary actions are avoided while assuring safety, thus optimizing integrity decisions.

An in-house software has been built to implement this model. A new reporting procedure has been developed with ILI vendors to generate more detailed three-dimensional (3D) corrosion morphologies which are input to this tool. Laser scan data or ILI data can be input for the integrity decisions of determining excavations, repairs, or derates.

How can other operators put this into practice? This model will be deployed to the PRCI members after the EC-2-9 project is completed. Operators can use this model for:

- Identifying features that need excavation based on ILI-reported sizing
- Calculating the derate pressures
- Making repair decisions in the ditch

By using this model, they will realize lower cost without compromising safety.

10:00 AM – Investigation of Biomethane Trace Elements Composition: A Tool to Better Know the Composition of the Gas Injected

Presenter: Amelie Louvat, RICE GRTgaz

Value to Operators: Several French operators of underground gas storages, gas distribution and transmission grids are working with RICE since 2016 on the characterization of French biomethanes. Impacts on network and end-users (corrosion, safety, security, etc.) are studied according to the nature and the concentration of trace compounds in biomethane. The up-to-day results of the study are very encouraging: the measured concentrations of the trace compounds in biomethane do not impact the downstream chain value. The injection of biomethane in aquifer storages should not create any additional impacts on the water quality. Based on this study, Storengy and Teréga, the two French underground storages operators, decided in June 2017 to open underground storages to biomethane by allowing the injection of biomethane from the national transmission network. This is a major step towards energy transition.

Description of the research: During three years, RICE GRTgaz sampled 60 biomethanes. These biomethanes come from 20 different injection points of local gas grids operated by GRDF and GRTgaz. The majority are produced from agricultural waste, some of them from waste from water treatment plants, and one from domestic waste. Sampling was done on pressurized cylinders and adsorbing tubes for organic compounds, and through trapping in acid solution for heavy metals. Samples of organic compounds were analyzed using TD-GC-MS (Thermal Desorption - Gas Chromatography - Mass Spectrometry). This technique allows the detection of organic compounds in a wide range of mass and concentrations. Two others analytical techniques were also used: GC-PFPD (Gas Chromatography – Pulsed Flame Photometric Detector) and µGC-TCD (Micro Gas Chromatography – Thermo Conductivity Detector). More than 300 compounds were identified with the analytical techniques, such as sulfur compounds, terpenes, hydrocarbons, siloxanes, metals, alcohols, ketones. A database was built with all the result coming from this analysis.

How can other operators put this into practice? This database can be useful to better assess the quality of renewable gases injection into the natural gas networks. Based on the obtained results, the knowledge on biomethane can be increased regarding the type of waste used for the production of biomethane. This study can help operators to establish their technical specifications/requirements for the biomethane injected on their network. The database can be also use as input for the national and/or international standards on quality of the renewable gas. Moreover, the knowledge of the biomethane quality can be also improve the analyzers proposed on the market by the manufacturers. Gas Industry can be the leader and help manufacturers to develop and propose analyzers that can meet the gas industry needs/requirements in term of biomethane injection.

10:30 AM – An Alternative Approach to the Assessment of Corrosion Anomalies within Pipelines

Presenter: Ryan O'Kelley, Atteris LLC

Value to Operators: Pipeline operators frequently utilize in-line inspection (ILI) tools to determine the level of wall thickness loss within a pipeline. However, the cost of an intelligent pigging campaign is sometimes not possible or economically viable, in particular for subsea to subsea pigging.

The approach presented utilizes the results of spot inspection data to provide statistical summary of the wall thickness loss for the entire pipeline. The method presents an alternative solution to the industry of unpiggable or difficult to pig pipelines.

The use of an externally mounted spot inspection tool has the additional benefits of greater flexibility in the choice of offshore support vessel and lower costs when compared to costs for intelligent pigging difficult pipeline systems or making pipelines piggable. An externally mounted tool also has no impact to the operation of the pipeline and inspections are non-intrusive.

Description of the research: This paper presents an alternative approach to the assessment of corrosion anomalies within pipelines. The presented methodology utilizes a statistical approach to determine the likelihood of a wall thickness feature exceeding the design allowable.

The methodology presented utilizes the results from a external spot inspection tool that can report wall thickness for discrete elements of the pipe wall (for example 1 mm2 or 1 cm2). Each scan encompasses a short length of the pipeline (for example a 1 m length) resulting in a large number of data points. These data points are samples from the overall pipe population and as such can be used to infer the overall pipe wall element population's statistical parameters.

To provide confidence that the data points are representative of the overall population it is important to define and understand the corrosion mechanisms that are credible for the pipeline. The corrosion mechanisms define the sampling locations that will be chosen to capture areas that will feature representative variations in wall thickness loss. Sub-populations may also be identified based on key locations (e.g. girth welds) and assessed separately to provide a refined assessment of the overall corrosion mechanisms. Statistical boot-strapping is performed on the data points to provide confidence bands around the sampled data with the most conservative extreme probability curve being utilized within the final assessment.

How can other operators put this into practice? Operators can utilize the presented approach to allow the inspection and characterization of corrosion anomalies within unpiggable pipelines or sections of piping or within pipelines which for it is not economically viable to undertake an intelligent pigging campaign.

The characterization can provide assurance of the corrosion mechanisms present within the assessed component as well as determine the likelihood of a corrosion anomaly exceeding the design allowable value.
The methodology has been employed on an existing project and a case study will be presented. The case study identified a number of relevant sub-populations to which the assessment methodology was applied. Application of the statistical assessment methodology to the pipeline inspection data detailed within the case study resulted in an estimated cost reduction of up to AU$15M compared to an in- line inspection campaign.

11:00 AM – Microchemical, Chemical, and Corrosion Samples

Presenter: Mohita Sharma, University of Calgary

Value to Operators: Microbiologically influenced corrosion (MIC) is an understudied area of corrosion because it needs to be addressed using a multifaceted approach in order to link the activity of microorganisms to corrosion. A pipeline's internal environment is generally anoxic, which is conducive for microorganisms to flourish. Operators often underestimate and/or do not understand the role of microorganisms in causing corrosion and use a variety of broad-spectrum biocides/corrosion inhibitors to curtail their growth. However, these chemicals are expensive, thus identifying and understanding the microorganisms and activities that flourish in pipeline environments is important in order to select appropriate biocides/corrosion inhibitors and to determine correct effective dosages. This particular study compared samples collected from a bypass piping segment at areas of localized internal corrosion (possibly due to microorganisms), and from areas of no corrosion. The sediments present in this piping segment were also used for the study. Collecting such samples from different affected and unaffected sites of a pipeline is very important in order to identify the key microorganisms that are directly responsible for MIC. The samples from this study were collected in two sets, where the first set was preserved onsite using isopropanol as a preservative and the second set was not chemically preserved, to keep the microorganisms metabolically active for performing more experiments with such samples.

Sharing the knowledge of proper sample collection and onsite preservation using simple methods for microbiological-based studies is the key element of this study. This information will subsequently help to identify sites and conditions conducive to MIC. The dissemination of the kind of knowledge generated from such studies, to operators, can help to prevent similar incidences and related losses from happening in the future.

Description of the research: Microbial and chemical analyses were conducted on samples collected from an internal corrosion release site at a crude oil facility to assess the potential for MIC. A total of 24 samples were collected from 4 locations on the same piping segment, representing the leak site (Location 1), an area adjacent to the leak site (Location 2), a non-corroded area (Location 3) and sediments collected from the piping segment (Location 4). Water chemistry, XRD (X-ray diffraction) analyses, microbial community analysis, and corrosion assays were performed on these samples. Notably, all samples were comprised of microorganisms that were indicative of an anoxic environment, including fermenters, methanogens, sulfur-/thiosulfate-reducers, and known biofilm-forming organisms - all metabolisms known to play a role in MIC. XRD results showed an enrichment of $FeCO_3$ at/near the leak site, and elevated levels of acetate at/near the leak site (17-20 mM) compared to the non-leak locations (2-10 mM). Collectively the data suggested that fermentative organisms producing organic acids, biofilm-forming organisms, and organisms able to withdraw electrons directly from the steel, contributed to the corrosion. Corrosion assays performed on these samples after incubation for one month showed the formation of localized pits of up to 20 µm in samples collected from Location 1, up to 4 µm in samples collected from Locations 3 (non-corroded area), and up to 10 µm in samples collected from Location 4. This suggests that microbial community present in the sediments may be responsible for formation of localized corrosion in the piping. Investigations related to microbial community composition of planktonic (free-floating) and sessile (biofilm) samples collected from the corrosion assay incubations are currently in progress to confirm this hypothesis.

How can other operators put this into practice? Operators facing issues related to localized corrosion can use this study as a model example of how to collect good quality samples from both the affected and non-affected sites where MIC is suspected. The importance of collecting samples from a control site is highlighted in this study which should be taken into consideration by operators to identify whether they are facing a MIC issue. Samples evaluated in this study will be deposited in an open-access molecular biology-based database which will compare samples from locations all over the world from different oil and gas environments; such data can ultimately help to predict the kinds of microorganisms that may be involved in MIC under different operating conditions. The techniques of preserving samples from sites with limited

resources will also be discussed in order to demonstrate the simple and straightforward additional few steps that operators can perform to collect high quality samples for failure analysis. This will benefit operations in the long term by confidently identifying root causes and mechanisms of MIC in order to better evaluate methods for its prevention.

1:00 PM – Clearing of Shorted Casings vs ILI Based Management – A Data Driven Approach to Preventing Failures and Managing Risk

Presenter: Shahani Kariyawasam, TransCanada

Value to Operators: Many older pipeline systems were designed with cased crossings. With time many of these casings have shorted with the pipeline. Considering corrosion mechanism shorted casings can have higher growth rates than non-shorted casings. In situations where heightened integrity management is required, such as special permit locations and high consequence areas, regulators require operators to clear all shorted casings. Clearing shorted casings, or where it is not feasible to clear replacing pipelines, has a very high cost.

There has been doubt among regulators and industry if ILI can effectively manage the corrosion rates in shorted casings. This study demonstrates that a sound ILI based program that considers the failure mechanisms and ILI performance at casings can safely manage shorted casings more effectively than clearing the shorted casings. This will reduce unnecessary remediation costs and prevent failures more effectively.

This work has been presented to the US regulator and has been seen favorably.

Description of the research: This study brings together extensive amounts of shorted casings data, incident data, and high-resolution ILI results and examines 1) where leaks and ruptures have occurred, 2) the likelihood of active corrosion under shorted casings, 3) the magnitude of corrosion rates manifested in shorted casings 4) the capability of current high-resolution ILI technology to detect the corrosion under casings and estimate the corrosion rates in shorted casings.

Wide-ranging operator experience and detailed data collected within 12 + years demonstrates that only a small fraction of shorted casings (electrolytic or metallic shorted) develop significant corrosion, and the resulting corrosion rates are detectable by repetitive ILIs. The data also demonstrates that ruptures are more likely in uncased and non-shorted pipe while shorted casings are more likely to leak. The corrosion rates observed under shorted casings have corrosion rates that have been safely and responsibly managed by ILI. Consequently, clearing shorted casings will prevent leaks while a sound ILI program will prevent both leaks and ruptures. The essential characteristics of such an ILI program are examined including the effects of the casing on ILI sizing accuracy.

Use of an ILI program manages the casings (shorted and non- shorted) and uncased pipe and provides both immediate and future integrity thus providing more effective integrity management and reducing unnecessary replacement or clearing of casings.

How can other operators put this into practice? Operators can use this work to build a sound ILI program that can manage casings and uncased pipe while avoiding unnecessary expensive replacements and clearing of shorted casings.

1:30 PM – Proposal of New HIC Test Solution with Good pH Stability for Fitness for Purpose Evaluation

Presenter: Daisuke Mizuno, JFE Steel Corporation

Value to Operators: Hydrogen Induced Cracking (HIC) is a major issue to develop sour resistant pipeline steels exposed to wet H2S environments. HIC susceptibility of steels is normally evaluated by HIC test method specified in NACE TM0284. In recent years, Fitness for Purpose (FFP) HIC evaluation has been discussed since it is being recognized the test method in TM0284 is too severe. In addition, FFP evaluation can expand usage of high strength steel such as X70 or higher grades. The FFP evaluation is performed in mildly sour conditions that have lower H2S and/or higher solution pH than the solution A in TM0284. Longer test period is required depending on the H2S gas partial pressure. Therefore, it is important to maintain test condition as constant as possible. High Strength Line Pipe (HLP) Committee in The Iron and Steel Institute of Japan (ISIJ) has investigated HIC test solution for FFP evaluations from view point of pH stability. In fact, it was confirmed that pH stability of test solutions influenced crack damage of the test specimens.

HLP Committee developed the new HIC test solution of 5 % NaCl + 0.93 N (CH3COOH + CH3COONa) (HLP solution) for FFP evaluation. In comparison with Solution C of 5 % NaCl + 0.4 wt% CH3COONa specified in NACE TM0284-2016 and EFC16, HLP solution provides excellent pH stability during HIC test in a wide range of solution pH. In particular, test solutions with initial pH lower than 4.0 tend to have significant pH drift because of corrosion reactions. However, pH drift of pH3.5 HLP solution was less than 0.2 in 14 days even under low specific solution volume to specimen's surface area. Therefore, HIC susceptibility of materials under a specific pH condition can be appropriately and stably evaluated under the strictly pH-controlled condition. Furthermore, it can eliminate a risk of test invalid by pH drift and frequent pH readjustment during HIC test.

One concern for use of HLP solution is high acetate concentration. Influence of high acetate concentration on corrosion and hydrogen absorption on specimens was investigated. HLP solution and Solution D showed similar pH dependence of corrosion rate. This observation suggests that high acetate concentration of HLP solution has no remarkable influence on corrosion behavior of test specimens. As well as corrosion behavior, hydrogen absorption behaviors obtained by electrochemical hydrogen permeation method in HLP solution and Solution D were comparable. Reproducibility of corrosion and hydrogen absorption in both solutions was secured.
HLP solution is an alternative solution for FFP in TM0284-2016. HLP Committee currently proposes to designate HLP solution as Solution D for the next revision of TM0284. In this presentation, pH buffer performance of HLP solution and its comparison with Solution C will be overviewed. Advantages and validity, of the HLP solution will be discussed from the practical use point of view.

Wednesday, March 6, 2019 – TRACK ONE: ADDRESSING CRACKS & DENTS

8:00 AM – Implementation of the MAT-8 Fracture Model into a Probabilistic Crack Management Framework

Presenter: Ted Anderson, TL Anderson Consulting

Value to Operators: This new probabilistic approach to crack assessment enables operators to maximize reliability per dollar spent on integrity actions. For example, the probabilistic framework can quantify the comparative costs and benefits of hydrostatic testing versus inline inspection of seam-welded pipelines, and it offers a risk-based approach to setting reassessment intervals as an alternative to traditional rules-based approaches.

In cases where operators choose hydrostatic testing to address the crack threat in seam-welded pipelines, the new probabilistic methodology is a valuable tool for planning and optimizing the test program. For example, probabilistic modeling can forecast the expected number of failures as a function of test pressure. Coupling this information with a probabilistic analysis of reassessment interval versus test pressure enables operators to optimize the test pressure(s) based on financial cost/benefit.

The probabilistic framework also aids integrity decisions following an ILI crack tool run. Each flaw detected by ILI is analyzed with the probabilistic model, and the flaws are ranked in order of probability of future in-service failure. This approach gives a more rational anomaly prioritization than the traditional approach based on burst pressure estimates because the future threat level of a given crack-like anomaly is driven by a combination of flaw size and the severity of pressure cycling at the anomaly location. There is a trade-off between the number of digs/repairs versus the prudent reassessment interval: more repairs justify a longer reassessment interval, based on a reduction in failure probability, but digs and repairs are costly. The probabilistic model offers a means to formulate a crack management plan that optimizes the allocation of the operator's integrity budget.

Description of the research: A new state-of-the-art pipeline fracture model was developed in the PRCI MAT-8 project, which was completed in early 2017. The MAT-8 fracture model is based on over 200 3D elastic-plastic finite element simulations of pipe joints with longitudinal cracks. Consequently, the MAT-8 model is significantly more accurate and has a stronger technical basis than traditional pipeline fracture models such as Log Secant and CorLAS.
As is the case with most fracture models, the methodology that resulted from the recent PRCI MAT-8 project has two important limitations:

1. The model assumes sharp planar cracks that are oriented perpendicular to the hoop stress. Moreover, the cracks are assumed to have simple profiles, such as semi-elliptical or canoe-shaped.
2. The model is deterministic, in that accurate burst pressure predictions require accurate input values for pipe dimensions, flaw dimensions, and material properties.

Following the conclusion of the MAT-8 project, Flint Hills Resources (formerly Koch Pipeline) and Shell Pipeline jointly supported an effort to address the above limitations and incorporate the improved methodology to their respective crack management programs. A modified version of the MAT-8 fracture model has been implemented into a probabilistic framework that accounts for real-world flaws.
Common seam weld anomalies differ from ideal planar cracks. For example, hook cracks are not aligned with the hoop stress, and cold welds have a finite tip radius. As a result, fracture models that treat these anomalies as ideal planar cracks tend to underestimate burst pressure. The probabilistic modeling approach uses an effective toughness distribution to account for the behavior of real-world seam anomalies. When these flaws are subject to pressure cycling, they do not immediately grow by fatigue. Rather, fatigue cracks initiate at seam anomalies over time. The probabilistic model accounts for time-dependent fatigue sharpening of flaws.

The MAT-8 fracture model has recently been modified to account for arbitrary flaw profiles. There are two traditional approaches for treating non-ideal flaw profiles: 1) approximating the flaw as a semi-elliptical crack whose length and depth correspond to the total length and maximum depth of the anomaly, and 2) applying an effective-area model to the "river-bottom" flaw profile. Method 1 can be very conservative. Method 2 is appropriate for metal loss, but it can be highly inaccurate for cracks. A recent finite element study on complex crack shapes resulted in an improved method to treat arbitrary flaw profiles.

How can other operators put this into practice? A number of operators, including Shell Pipeline and Flint Hills Resources, are already benefiting from this research. The probabilistic crack assessment model has been successfully applied to ILI crack datasets, as well as hydrostatic test planning & optimization. The probabilistic methodology, which incorporates the modified MAT-8 fracture model, has been implemented in a prototype software application. A joint-industry project (JIP) is currently underway to refine the methodology and implement it in a commercial-grade cloud-based software application. The JIP is administered through PRCI and is open to all operators. The cloud-based software will be eventually be available for licensing to operators who are not JIP members.

8:30 AM – Full Scale Cyclic Fatigue Testing of Crack-in-Dent and Development of Frame Work for Life Prediction

Presenter: Udayasankar Arumugam, Blade Energy Partners, Ltd.

Value to Operators: The goal of this research (Task Group 3) is to perform full-scale experimental investigation of dent containing crack colonies under cyclic pressure and influenced by environment to determine the crack growth rate using a combined micro-and macro-mechanics approaches and to establish a frame work for life prediction of cracks in dents in liquid pipelines. The findings from this research would benefit members with a frame work to manage integrity of dents associated with fatigue cracking and corrosion, and mitigate in a timely manner. However, since the complexity of geometry of dent and size and distribution of fatigue cracks, application of this frame work will be preliminary and detail will be case-by-case.

Description of the research: ASME B31.8 states that "Dents that contain stress corrosion cracking or other cracks are injurious to the pipeline" and therefore, require immediate attention by the Operators. Dent containing crack fields (colonies) are often observed in liquid pipelines. Because of their colony appearance, these cracks in dents are often believed to be associated with stress corrosion cracking (SCC). However, the recently completed PRCI research "Study of the Mechanism for Cracking in Dents in a Crude Oil Pipeline – Task Group1" showed evidence of a combined mechanism of corrosion pitting and fatigue cracking from the fracture surface. Further, an attempt was made to estimate the crack growth rate as function of stress intensity factor (K) using micro-mechanics approach. These observations prompted PRCI to launch a further study of full-scale experimental investigation of dent containing crack colonies under cyclic pressure and influenced by environment to determine the crack growth rate. A combined micro-and macro-mechanics approaches are used to establish a frame work for life prediction of cracks in dents in liquid pipelines (PRC-328-133702, MD-1Q).
A total of 6 pipe samples containing dent with crack/corrosion excavated from a retired liquid pipeline were used for the full-scale fatigue test. The experimental test setup consists of four major components: (1) a computer-controlled hydraulic pressure cycling system, (2) an environment chamber containing NS4 solution mounted on the dent region to simulate field environment condition; (3) a crack growth monitoring system including Direct Current Potential Drop, Clip gage and Strain gage; and (4) data acquisition and real-time data monitoring system. The cyclic pressure range used in the test was 78 to 780 psig (MOP = 72% SMYS) with R=0.1 and frequency of 0.0526 Hz. So far, 4 out of 6 samples were completed and the remaining are on-going. The preliminary results from this full-scale fatigue tests showed the cracks in dents exhibit leak-before-rupture behavior which were expected based fracture mechanics calculation using the material toughness

and the through-wall crack size. However, subsequent pressure cycling after the leak could cause a rupture originating from the crack in dents. The number of cycles to failure (i.e., leak) in dents depended on the initial crack size in dent, dent shape & size, and with or without environment. Based on the full-scale test results and using the historical operation pressure fluctuation data, the remaining in-service life can be calculated with or without environment.

In this paper, the experimental setup and approach used in the fatigue test are described first. Then, the result from each test is presented with the estimated in- service life. FEA approach to determine the stress intensity factor (K) values for crack in dent are presented and compared with experimentally determined K- values based on the fatigue crack growth rate. Finally, a proposed frame work for life prediction of cracks in dents which incorporates into the available life prediction models (e.g., corrosion-to-fatigue-to-failure models) will be presented including gap analysis, if any, and recommendation for future scope of the work.

How can other operators put this into practice? This research provides a frame work for life prediction of cracks in dents. Operators, based on the in-line inspection or field NDE on dent geometry and crack size/location, can utilize the methodology and procedure proposed in this research based on full-scale fatigue tests to estimate the remaining life and develop better dent integrity management plan and mitigation strategy in a timely manner. However, it is anticipated that due to the complexity of geometry of dent and size and distribution of fatigue cracks, application of this frame work will be preliminary and detail will be case-by-case.

9:00 AM – Towards a Reliability-Based System-Wide Integrity Management Approach for Pipeline Dents

Presenter: Nader Yoosef-Ghodsi, Enbridge

Value to Operators: Management of dents has been a challenge for the pipeline industry due to the inherent feature complexities, inspection tool limitations (related to identification of cracking within dents), and lack of an available fitness for purpose approach. Current regulations are lagging recent industry developments, as they are still based primarily on feature depth and the presence of interacting features instead of thorough assessment of the feature severity. This potentially lacking efficacy has been demonstrated by recent failures (such as described in NTSB Pipeline Accident Brief 17-01) which have occurred despite apparent adherence to industry regulations and best practices. Operators typically rely on additional criteria to augment these regulatory requirements to ensure safety of their lines and avoid any release of product to the environment. These additional criteria are often highly subjective and solely qualitative, with additional mitigation activities selected based on experience which is not necessarily consistent among operator groups. While these combined (regulatory and operator-specific) criteria have been reasonably effective for ensuring pipeline safety, the cost of dent management programs typically far exceed the level of threat posed by this type of feature in the industry. Also, sole reliance on subject matter expertise hampers auditability and leaves significant room for human factors to impact safety. While strong research efforts have been made (through PRCI and others) to enhance industry knowledge regarding this threat, studies focus on only small portions of the overall problem and leave large gaps when looking for a unified method for all dents. This research provides a framework that allows for a consistent quantitative analysis of the threat for large complex pipeline systems with a variety of different dent morphologies and feature interactions. Ideally, this framework will allow for optimization of dig programs, so that operators can ensure that safety is maintained while minimizing unnecessary integrity spending.

Description of the research: This research has led to the development of a novel probabilistic dent assessment framework which facilitates the analysis and management of the dent threat for large pipeline systems based on inline inspection results. This framework includes a ranking method (used to identify those features most likely to require further analysis or mitigation), a detailed analysis method (used to leverage advanced engineering techniques to quantitatively prove the

safety or identify mitigation requirements), and a quantitative means of determining a safe excavation pressure for the feature(s). The ranking method leverages simple strain calculations (based on ASME B31.8 recommendations) and expands upon them through the use of probabilistic multipliers which account for geometric properties, feature interactions, fatigue susceptibility, and their inherent uncertainties. Once ranked, the framework requires performance of probabilistic finite element analysis for in-depth evaluation of the stress-strain field of complex and/or potentially injurious features to quantitatively determine their probability of failing different limit states (strain, burst, and/or fatigue). This analysis accounts for the properties of the pipe, dent, and interacting features, the operating condition and history of the line, load sequencing associated with the dent (including restraint condition), and associated uncertainties. Finally, a safe excavation pressure is determined through additional probabilistic finite element analysis which accounts for potential cracking within the dent and the effects of changes to the restraint condition and pipe supports that may lead to rebounding or rapid crack growth within the feature. These techniques all combine inline inspection results and engineering analysis with their uncertainties, providing a means for the quantitative assessment of this complex threat. Efforts have been made to validate (and where possible to calibrate) the techniques developed in this study through comparison to experimental results, field findings, and historical failures; the resultant framework shows good alignment with existing integrity program decision making.

How can other operators put this into practice? When combined with existing regulations and decision-making systems, the proposed dent analysis framework has the potential to enhance or replace existing dent assessment and integrity management processes, as it provides complete methods for feature ranking, detailed engineering assessment, and safe excavation pressure definition. Some of the key factors to be addressed when implementing this method include: calibration of factors, operator competency development, and regulatory acceptance. The proposed models require calibrating the model to a given operator's experience (primarily for the ranking method) and defining appropriate permissible probability of failure values (which can be selected based on the specific operator's risk tolerance and definition of ALARP). From a competency perspective, implementation of the ranking model requires some basic understanding of probabilistic methods but these skills and associated methods can be easily developed using available industry publications. Probabilistic finite element analysis is more complex and requires significant expertise in a variety of fields (reliability analysis, finite element analysis, solid mechanics, etc.); however, these skills are available among many recent graduates and/or several finite element consultants. Pursuit of regulatory acceptance for this (or any) framework requires substantial validation, long-term development and testing of the model, and unified industry backing, meaning that it is unlikely that this framework can be included within any practical timeframe. As regulatory change is not expected in the short-term, this framework is recommended only as a means to update and enhance existing operator-specific mitigation criteria, and is recommended to augment the existing regulations. Operators can implement the proposed framework as a supplementary process to help check current criteria with the goal of ensuring that all potentially injurious features are identified. Following a testing and calibration phase, this methodology could be used as a means to enhance existing processes and support further optimization of dent integrity management programs.

9:30 AM – Leveraging Industry Data Sharing to Support Improved Crack Management Programs at a Liquids Operator

Presenter: Steven Bott, Enbridge Liquids Pipelines

Value to Operators: A successful crack management program must identify and mitigate crack defects before they fail in service. Crack ILI can be a critical tool that operators can use to assess line condition. However, unlike metal loss ILI, many operators have limited experience with crack ILI and thus have reduced ability to assess the capabilities and demonstrated performance of crack ILI technology when used as part of an integrity management program. NDE-4E and the follow-up project NDE-4-7 have provided industry with the ability to collect crack ILI program results from pipe with a wide range of

vintage, characteristics and condition. In short, industry data sharing allows operators to pool data to build a relevant data set to explore demonstrated performance of crack ILI that few operators have on their own.

The NDE-4E suite of projects provides examples for operators on how to use their own data to test tool performance not just as a check against vendor specification but to understand the reliability achieved on their system based on the implementation of crack ILI. In addition, characterization of the typical range of demonstrated performance supports operator decision making that could allow improved effectiveness and/or improved efficiency. The technology transfer from NDE-4E can be used to develop or support crack management programs that use crack ILI as a threat assessment tool, with a feedback loop to existing best practice documents such as API 1176. When taken together, these benefits lead the operators, vendors, regulators, and other stakeholders to a common understanding of the successful use of crack ILI for crack management.

Description of the research: Characterizing the performance of crack In-line inspection (ILI) technology is critical to implementation of an ILI-based crack management program as ILI performance directly affects an operator's ability to be effective and efficient while maintaining high reliability. PRCI projects NDE-4E and NDE-4-7 both focus on collecting high quality correlated ILI and non-destructive examination (NDE) results from operator members to assess the range of demonstrated performance from crack ILI technologies. In addition, a guidance document highlighting the key technology transfer concepts from the technical research will allow operators to more easily understand how to manage crack ILI performance to maximize both effectiveness and efficiency of crack management programs.

Enbridge has applied similar statistical approaches to assessment of crack ILI detection, identification, and sizing performance have to those employed as part of the NDE-4E work. Data visualization and statistical analysis have been used to make the results of the analysis more accessible so that the trends and implications of the demonstrated performance are clear to a broad stakeholder audience. As discussed in the NDE-4E technology transfer document, the links between crack ILI performance and program performance have been considered in the crack management program which allows Enbridge to maintain effective programs in alignment to pre-defined reliability targets. Demonstrated tool performance is also used to improve efficiency of ILI response criteria and to identify the most impactful places to drive continuous improvement of the crack management program and crack ILI technology. Specific examples of how the approaches pioneered as part of NDE-4E have been used by Enbridge will be provided to illustrate the links between crack ILI performance and integrity management processes. In addition, important trends in crack ILI performance apparent in Enbridge experience will be shared to provide context for other operators.

How can other operators put this into practice? While NDE-4E and NDE-4-7 do not identify particular ILI vendors or inspection tools, they do provide a range of expected performance and highlight where the technology has common strengths and limitations across vendors. Enbridge is sharing specific examples of trends to provide information and suggested approaches that may be useful for other operators implementing crack ILI as part of their crack management programs. In addition, the approaches and results may support further exploration or analysis using the data collected from across operator members within PRCI.

The NDE-4E technology transfer document provides examples on how crack ILI performance data can be used to improve the effectiveness and efficiency of crack management programs. Cases studies on the impacts of considering the links between crack ILI performance and crack integrity management provide examples on how to implement the guidance provided in NDE-4E and other industry documents such as API 1176 into practice.

10:30 AM – A Comprehensive Assessment of Inspection Technologies for Characterizing ERQ Seam Anomalies and Impact on Pipeline Integrity Management

Presenter: Mark Piazza, Colonial Pipeline Company

IM-3-1 was approved to support the evaluation and improvement of in-line-inspection (ILI) technology to identify and characterize features in ERW-seam-welded pipelines. This project addresses a key industry research need to confirm and validate that periodic use of current ILI methods are the best means to identify and respond to anomalies present in the longitudinal seam of ERW pipe.

By providing a consistent and objective basis for determining the performance capabilities of the current inspection technology systems, particularly as the performance relates to critical flaw sizes, discriminating feature types, and sensitivity analysis of engineering models, operator costs should be optimized to target repair and remediation decisions on anomalies that are injurious, and provide the confidence that non-injurious anomalies are accurately characterized and do not represent a current threat to pipeline integrity.

The objective of this project is to provide performance evaluation data for three different ILI technologies identifying and characterizing features, anomalies and defects in the longitudinal seam of ERW Pipe, and will produce performance qualification data in terms of detection (POD - Probability of Detection), identification (POI - Probability of Identification) and sizing capabilities.

The project includes a series of high-number of ILI tests (34 to 57 runs per ILI system) conducted at the 12” liquid flow loop that was recently constructed at the PRCI TDC in Houston TX. The ILI systems performance testing process will leverage the availability of ERW retired, former in-service ERW pipe samples that have been contributed by pipeline operators for the project.

This project is part of the ERW Pipe Program (IM-3 Program) and is also closely tied to the NDE-4 Program on Improving/Enhancing ILI Technologies. The results of this project will be consolidated with the outcomes of all projects being implemented under the ERW Pipe Program and will form the basis for a comprehensive guideline for managing the integrity of ERW pipelines, an important outcome for the pipeline industry. The project work is also linked to other initiatives outside of PRCI, including the API Crack Management Recommended Practice (RP 1176) and PHMSA's parallel ERW Program, Phase 2.

PRCI engaged Blade Energy Partners to conduct the evaluation of the ILI data obtained from the repeated testing at the TDC. The trials include 1) the review of the testing protocols, 2) the supervision of the pull-through runs to ensure feature anonymity, ILI Intellectual Property protection, and the monitoring of key run-parameters, and 3) the statistic validation of the ILI tool performance in terms of their capabilities, limitations and potentials in feature/defect detection, discrimination and sizing.

The resulting data is analyzed, aligned, compared to truth data and evaluated by Blade, with the process and findings presented in this paper. Quantitative measures of detection and sizing performance, along with partial truth data aiming at the improvement of ILI technologies used, will be disclosed in-confidence to the individual ILI technology providers participating in this project.

11:30 AM – A Novel Method in Assessment of Corroded Steel Pipe in Water Lines

Presenter: Ali Alavinasab, Xylem

Value to operators: Pipelines are the most common and feasible method for transporting water, oil, and gas. In general, pipelines may deteriorate during the service period. Pipeline defects may occur for different reasons such as coating degradation, local environment or third-party damage during fabrication. Locating and assessing these defects is critical for the operator to prevent any service interruption. In theory, the older pipeline requires more attention and integrity assessment. Using the current enhancement in damage detections, pipeline inspectors are able to scan their line with high-resolution inspection tools. It should be noted that all defects in pipelines are not critical and do not need to be repaired. Therefore, the proposed assessments will help operators to determine the risk of failure associated with the defect dimensions and amount of corrosion and ultimately, they can make a better decision regarding the timing and extent of the required repairs. To answer these needs, there are different codes and standards were developed for assessing a defect in pipelines. These codes and standards have been improved over the time when our experience regarding the failure mechanism of buried pipeline improved. Most of the common methods in industry have been developed mainly for oil and gas pipelines, even though there are significant amount of steel pipes operating in water industry. To fill this gap, a novel method was proposed to cover the steel pipes in water industry which normally have lower strength in comparison to oil and gas industry. The proposed approach provides less error in predicting failure pressure of defected steel pipes in comparison to other well-established levels one (1) assessment methods in the industry. Therefore, the results would be less factor of safety and more saving for the end users.

Description of the research: Steel pipes have been used widely in water, oil, and gas transmission pipelines. Like any engineering structure, pipeline fails occasionally. The most common failure causes are mechanical damages and corrosion. In this research, the most common level 1 assessments procedures in the pipeline industry were studied, including ASME B31.G, Modified ASME B31.G, PCORRC, API RP 579, and DNV RP F101. Mentioned assessment procedures were used to predict the failure pressure of pipe in the presence of damage. A set of experimental data, found in literature, were utilized in this study for comparison and validation purposes. The experimental data consists of steel pipes with different diameters and different size (length and depth) defects on the pipe. All of the predictions obtained from level 1 assessment methods were compared to actual experimental data. Average prediction errors were calculated for each method to acquire their level of conservatism. Studying different methods led to a novel level 1 assessment method, Remaining Strength of Corroded Water Pipeline (RSCWP). RSCWP was developed to predict failure pressure of defected steel pipes. Predicted failure pressure, using RSCWP, was compared to the aforementioned experimental data. The prediction error was calculated and compared to the error in the other five level 1 assessments. The findings show that the error associated with the proposed method (RSCWP) is lower than different level 1 assessments methods. It is observed that the proposed method has the lower level of conservatism in comparison to other methods. Normally oil and gas industry have higher level of regulation and uses steel pipes with higher strength in comparison to water industry. Novelty of this research is in filling this gap by proposing RSCWP level 1 assessment method which developed sore specifically for steel pipes in water industry.

How can other operators put this into practice? Most of the operators and utility companies are familiar with Fitness for Service (FFS) procedures. Level 1 assessment is a part of FFS. Most of these methods originally designed and developed for oil and gas industry which uses higher level of regulations and pipes with higher strength in comparison to water industry. By this newly developed and proposed method, operator companies, and more specifically water industry, can use this as another level 1 assessment method. The proposed plan is straightforward and, other standard methods in the industry such as ASME B31.G, Modified ASME B31.G, PCORRC, API RP 579, and DNV RP F101 can easily be replaced by the proposed method in this research to predict the failure pressure on defected pipes. Assessing defected pipes to repair or

replace them in the right time will save money for operators. RSCWP will perform the task more accurately in comparison to other methods.

12:00 PM – Evaluating SCC in Pipelines with IWEX

Presenters: Harvey Hains, Applus RTD & Ben Hanson, Kinder Morgan

Value to operators: The project goal is to develop the means to determine accurate failure pressure prediction for SCC using in-ditch and ILI inspection. With this information the operator should be able to better derive a reliable and more accurate means for calculating remaining life for SCC colonies, given the capabilities and limitations of current EMAT technology.

Description of research: This project was proposed to span over 3 years. Year 1 focused on developing IWEX technology processes and procedures for gathering accurate in-ditch ultrasonic imaging data for SCC. Year 2 comprised field trials, validation and improvements, as needed. Year 3 will include validation by means of burst tests to determine the model that most accurately predicts failure pressure based on IWEX measurements. This presentation will cover research performed in Years 1 and 2.

The project has compared sizing of SCC colonies using X-ray computed tomography to IWEX ultrasound imaging for 2 sets of 4-in wide plates containing SCC. In addition, some of these samples have been destructively evaluated by breaking open cracks frozen in liquid nitrogen or sectioning through multiple parallel cracks with subsequent polishing of samples. Comparisons of these samples will be presented across profiles of cracks in an SCC colony. In the second year of the project IWEX UT images of cracking are being compared to EMAT ILI data. The largest of these crack colonies are being selected for the planned 3rd year study for burst testing of samples.

The methods developed in this study should help other operators to improve their ability to qualify ILI crack tools and predict burst pressures from in-ditch UT imaging of cracking.

12:30 PM – MAOP Verification of Facility Piping

Presenters: Peter Veloo, Exponent and Michael Rosenfeld, Kiefner & Associates

Value to Operators: The Pipeline and Hazardous Materials Safety Administration (PHMSA) has proposed modifications to the federal rules governing the transport of natural gas. Specifically, the proposal calls for the verification of the maximum allowable operating pressure (MAOP) for assets that have been grandfathered into current service or are missing records of a hydrostatic pressure test. PHMSA's proposed new rule can be satisfied by one of several methods, including hydrotesting, de-rating, replacement, and engineering critical assessments based on either in-line inspection or alternative technologies. Our research focuses on alternative technologies method as discussed in PHMSA's proposed new rules. The output of our work would be a program that may be adopted by operators seeking to perform MAOP verification on assets that cannot be in-line inspected or inspected by methods that are cost-prohibitive. The basis for this research is the utilization of nondestructive examination (NDE) to characterize manufacturing and construction flaws and defects as well as verify material properties. An NDE-based approach to MAOP verification can be a cost-effective option for an operator's unpiggable facility piping. PHMSA's proposed MAOP verification rule includes a schedule for completion. Operators may prioritize their MAOP verification workload based on the probability that an asset would fail a strength test. Alternatively,

this workload could be prioritized based on the probability of failure during routine service due to fatigue. Operators are more likely to combine both metrics alongside consequence and reliability considerations.

Description of the research: Proposed changes to the federal regulations governing the transport of natural gas by pipeline will introduce requirements for operators to verify maximum allowable operating pressure (MAOP) of piping without traceable, verifiable, and complete (TVC) records of a hydrostatic pressure test. Pressure testing is mandated to ensure that existing manufacturing and construction defects remain stable during routine natural gas service. The Pacific Gas and Electric Company's (PG&E) Facility Integrity Management group has developed a program that leverages nondestructive examination (NDE), in-line inspection crack datasets, and probabilistic fracture mechanics to verify MAOP in lieu of performing a mid-life TVC hydrostatic pressure test. The extent of facility piping that requires MAOP verification is informed by an exhaustive records research program, which identifies TVC strength test and material records for all station features. In order to perform a prioritization, probability density functions of defects were created using industry databases of crack distributions determined by in-line inspection. Using fracture mechanics, the probabilistic failure pressure and remaining life are computed from the probability density functions, pipe characteristics, current operating pressure, and operating history. The highest priority assets for MAOP verification are then subjected to field NDE. Pipe body, long seam, and girth weld defect sizing is performed using existing magnetic, radiographic, and ultrasonic based testing technologies. Material properties, including strength and chemical composition, are estimated using extensively and independently validated NDE tools. Fracture toughness values, where unavailable, can be estimated from PG&E's materials testing program. The proposed MAOP validation methodology and its application to five existing PG&E facilities will be presented.

How can other operators put this into practice? Operators can readily implement the PG&E station piping MAOP verification process presented here. PG&E's research leverages existing in-house NDE, materials testing, and fracture mechanics capabilities that are routinely applied for integrity management activities. For example, an operator's typical in-line inspection validation program currently uses NDE technologies to detect and size manufacturing and construction defects. This program has the necessary operator qualifications, job-aids, and work procedures for this set of activities. Presently, operators have in-house or contractor capabilities to perform fitness-for-service (FFS) calculations for ILI indications that are detected and field-validated. These FFS calculations include predicted failure pressure and remaining life models which can be utilized for MAOP verification. Modifications to the present approach may be required to convert traditional deterministic inputs to the recommended probabilistic inputs. In response to PHMSA's proposed rules for opportunistic material verification, operators are presently at various stages of maturity with respect to developing in-house and accessing contractor NDE capabilities for determining material properties for pipeline assets. These NDE capabilities can be deployed to determine material properties of assets requiring MAOP verification. PG&E has developed a prioritization scheme based on proprietary databases of manufacturing crack-like defects in pipe that are categorized vintage and seam type. The PHMSA Voluntary Information-Sharing (VIS) system working group aims to consolidate ILI data from pipeline operators to create shared databases.

Wednesday, March 6, 2019 – TRACK ONE: SAFETY MANAGEMENT

2:00 PM – NDE Technician Qualifications Forum: Industry Improvement Efforts

Presenters:

Michael Sens, Chevron
ANST – Creating an Oil & Gas Industry Sector Qualification

Andri Orphanides, API
API – Meeting the needs of industry with new NDE Qualifications

The role of an NDE technician is a key part of ensuring pipeline integrity; therefore, the need to understand and enhance the competency level of NDE technicians has been become essential. Two organizations are in development to establish competency levels for NDE technicians: American Society of Non-Destructive Testing (ANST) and the American Petroleum Institute (API). Both organizations are in the process of creating new qualification programs. Today's forum will provide an overview of each of their efforts. This forum will provide the opportunity to take an in-depth look at their programs and understand how they can be used to ensure the competency levels of NDE technicians.

3:00 PM – Determining the Impact of Human Factors on the Performance of In-service NDE

Presenter: Jane Rau, Jtrain

Value to Operators: The term "Human Factors" has become a buzz phrase in the pipeline industry, and rightfully so. Root cause analyses of many failures point to human error as the cause. However, in the pipeline industry "Human Factors" generally refers to ergonomics, fatigue, stress, lack of resources and communication. This research looks at Human Factors from an educational viewpoint; how is transfer of knowledge from SME's to NDE technicians presently performed and how can it be improved to ensure actual learning occurs; not just rote memorization to pass a test. Being a knowledgeable SME does not guarantee an understanding of teaching and learning. This presentation will discuss how research-based learning strategies and best practices in teaching and learning can improve transfer of knowledge and competence for NDE technicians.

3:30 PM – Competency in the Pipeline Industry: An Industry Survey

Presenter: Reena Saheny, PBOK

Value to Operators: What difference does this research make in operations of a pipeline system?
Industry is increasingly focusing on managing risk and enabling continuous improvement through the effective implementation of safety management in support of safer pipeline operations. A key aspect of effective safety management systems is managing human factors – including competency of personnel in key roles. Additionally, regulators in Canada and the United States are focusing on competency management of industry personnel during inspections rather than the historic emphasis on training and development.

Thus, the value of this work to operators will be in the form of understanding a baseline maturity of the industry in defining competency requirements within an organization. For the purposes of this project, competency has been defined as the

combination of theoretical knowledge, skills, experience, and behavior necessary to perform a task or role. As such, the data collected from this survey will enable a number of initiatives such as the identification of gaps in baseline industry competency requirements across the pipeline lifecycle. The data acquired could then be used to build a 'roadmap' as a guide for maturing industry-wide competency through various forms of knowledge transfer (e.g., training and development opportunities).

In addition, this survey complements work ongoing in other parts of the industry in the area of competency management such as CEPA's 2018 initiative to develop a guidance document on competency management.
This project was identified during the 2017 Joint Technical Committee (JTM) meeting in Colorado Springs at the Human Factors Workshop. PRCI was identified as the lead for this project and funding was secured off-ballot.

Description of the research: The outcome of the survey is intended to establish a baseline of competency requirements in the pipeline industry. In order to meet this outcome, the target audience for the survey has been identified to be 6 to 10 individuals in oversight roles within PRCI, APGA and EPRG companies. It is intended that the survey would include 10 to 15 companies drawn from this target group. Further, the survey is intended to review requirements across the pipeline lifecycle drawing on a base of ~60 questions (with the intention that a typical participant would answer ~30 questions based on branching within the survey design). The results of the survey would then be used to analyze maturity as a function of a number of key parameters within industry including (but not limited) to company size, geography, role (e.g., operators vs., service provider) and other parameters that may emerge through detailed analysis of the survey data.

Analysis of results will indicate normative practices in addition to leading practices from North America, Australia, and Europe within respondents. These leading practices may become a basis for further development of competency management guidance in future research projects.

How can other operators put this into practice? Even if an organization does not participate in the survey, the information can be used to compare and benchmark how the company ranks relative to industry. As such, the survey results can provide a valuable tool to understand maturity of a single organization relative to industry. This would also provide the ability to develop individual (i.e., company-specific) roadmaps to mature practices in the area of competency management. Operators can use this exercise to illustrate due diligence in the area of competency management.

Tuesday, March 5, 2019 – TRACK TWO: LEAK DETECTION & RIGHT OF WAY

9:30 AM – Application of Machine Learning to Improve Lead Detection Capabilities of Distributed Temperature Sensing (DTS) Systems

Presenter: Maria Araujo, Southwest Research Institute

Value to operators: Small leaks from hazardous liquid pipelines can pose a significant safety and environmental threat. The timely mitigation of such leaks requires that they be detected early after their onset. The current state-of-the-art computational pipeline monitoring (CPM) systems used for leak detection are not suited to detect and locate very small leaks.

A prominent alternate technology currently being considered for small leak detection is distributed temperature sensing (DTS), which comprise optoelectronic devices that measure temperatures by means of optical fibers functioning as linear sensors. Temperatures are measured along the optical sensor cable to provide a continuous profile. A high accuracy of temperature determination can be achieved over great distances.

While such systems can be very sensitive, a downside is that many minute temperature changes can be measured. There are many physical phenomena that can cause a temperature change along a pipeline. Many actual leaks may result in only very small temperature gradients at the fiber location or change at such a slow rate that they could get masked by the rate-of-change algorithm. It is not a trivial exercise to differentiate a temperature change from an actual leak from an unrelated activity. Unless a means of reliably making this distinction can be deployed, DTS systems can be prone to either missing events or generating inordinate numbers of false alarms.

To address these shortcomings, this research utilized highly advanced techniques to classify and detect leak signatures. Rather than relying on thresholds and baselines, the work discussed in this paper utilizes machine learning (ML) techniques for which classifiers are trained to detect leak signatures. This resulted in a more robust methodology for detecting leaks and allows for the detection of smaller leaks than are currently detected by typical DTS systems, with low false alarm rates that can be readily leveraged by operators.

Description of research: The timely detection of small leaks from liquid pipelines poses a significant challenge for pipeline operations. One technology considered for continual monitoring is distributed temperature sensing (DTS), which utilizes a fiber-optic cable to provide distributed temperature measurements along a pipeline segment. This measurement technique allows for a high accuracy of temperature determination over long distances. Unexpected deviations in temperature at any given location can indicate various physical changes in the environment, including contact with a heated hydrocarbon due to a pipeline leak.

The signals stemming from pipeline leaks may not be significantly greater than the noise in the DTS measurements, so care must be taken to configure the system in a manner that can detect small leaks while rejecting non-leak temperature anomalies. There are many factors that influence the frequency and intensity of the backscattered optical signal. This can result in noise in the fine-grained temperature sensing data. Thus, the DTS system must be tuned to the nominal temperature profile along the pipe segment. This customization allows for significant sensitivity and can utilize different leak detection thresholds at various locations based on normal temperature patterns. However, this segment-specific tuning can require a significant amount of resources and time. There is a significant need and interest in advancing existing DTS processing techniques to enable the detection of leaks that today go undetected by DTS due to their signal response being too close to the noise floor and/or require significant resources to achieve positive results.

This research focused on using machine learning (ML) techniques for which classifiers were trained to detect leak signatures. Initial proof-of-concept results provide a more robust methodology for detecting leaks and also allow for the detection of smaller leaks than are currently detectable by typical DTS systems, with low false alarm rates.

How can an operator put this into practice? This research can be extremely beneficial to operators because it successfully demonstrated an initial, proof-of-concept ML-based detection algorithm for leaks that likely exceeds the detection capabilities of current DTS systems. These initial results show that the algorithms developed under this effort were not only capable of finding leaks that were missed by existing DTS systems, but also reduced false positive rates.

In addition to DTS systems, there is direct extensibility of the work performed in this project to several other applications, including applying similar techniques to distributed acoustic sensing (DAS) systems. DAS systems show enormous potential for being an effective pipeline leak detection technology. However, due to their high susceptibility to environmental acoustic conditions, those systems are highly susceptible to false alarms, and current techniques to reduce those false alarms many times result in missed leak detection events. As such, those systems can benefit significantly.

The resulting algorithm and methodology can be put into immediate use in existing DTS systems and can also be adapted for DAS systems.

10:00 AM – SmartBall Technology: An Innovative Multi-sensor Tool for Long Inspection of Oil and Gas Pipelines

Presenter: Carine Lacroix, GRTgaz – RICE

Value to operators: SmartBall is a free-swimming inline inspection tool that is equipped with acoustic activity, pressure, temperature, magnetic and inertial mapping sensors. This system is compatible with pipelines diameter as small as DN 150.

Acoustically based, the SmartBall is able to detect pinhole size leaks on oil and gas pipelines. Based on this technique, unppigable pipelines could be better characterized from the gas pressure, temperature, to all information that could be measured by sensors integrated in the metallic core.
SmartBall can be considered as a powerful technology for gas detection but even more as a vector of sensors to increase the operational knowledge of unpiggable and piggable pipeline characteristics. An example would be the integration of a sensor for the localization and georeferencement of gas networks with a classe A precision (+/- 10 cm precision of the integrated sensor).

In 2017 PureHM and Smartball worked with PRCI in the “NDE-3-2A, Integrity Assessment of DTI Pipelines Using High Resolution NDE in Select Areas, Year 3.” PureHM was demonstrating lowering its industry leading lower leak threshold beyond 114ml/min and detecting small inner pipeline diameter changes.

Description of the research: The performances of this gas leak detection system have been tested in RICE GRTgaz facilities (France, Paris area) in natural gas conditions, in 2017. Static tests from 4 bar to 16 bar have been conducted, as well as dynamic test on a ~20 m bend test. First results were successful with small gas leak detection, less than ~0.5 - 0.8 mm for 16 bar conditions. RICE GRTgaz intends to complete this performance test by increasing testing pressure up to 60 bar and is looking for a part of its network to be inspected in live conditions.

GRTgaz is currently looking for industrial collaborations to optimize gas inspection based on SmartBall and/or to develop the idea of using SmartBall as a georeferencement tool. Then the proposed developments could focus on a real-time monitoring inspection or the integration of high resolution sensors for precise mapping of gas networks.

How can an operator put this into practice? The overall need for gas leak detection using this sort of tool is not well quantified and can depend on a countries specific regulations. With relatively fast development, SmartBall for gas application could be moved into the final stages of development

The georeferencement topic would need more development effort, as if it would be necessary to select and integrate the adapted sensors. Then, SmartBall can be seen as a vector of sensors to better know the characteristics of gas network. The time needed to achieve final SmartBall version depends on the functionality needed by gas operators.

10:30 AM – Autonomous Aerial Detection of Liquid Hydrocarbon Leaks in Water Bodies

Presenter: Maria Araujo, Southwest Research Institute

Value to Operators: Since 2010, there have been more than 1,300 crude oil spills in the United States (one crude oil spill every other day). A portion of these spills occur in onshore water crossings (e.g. rivers). These water leaks and ruptures have gone unnoticed for weeks before companies manage to detect the problem. Because of the nature of water bodies, these leaks can reach other areas rapidly; as such, early detection of leaks on water is of pivotal importance. Unfortunately, there are very limited commercially available effective technologies for crude on water leak detection, thereby increasing the need to develop a robust remote sensing technology that can reliably detect leaks on water bodies. This presentation will discuss results of an ongoing R&D project that is focused on using camera sensors to autonomously detect crude oil slicks on water surfaces on an aerial platform for real-time remote inspections of water crossings.

Description of the research: Southwest Research Institute® (SwRI®) has developed the Smart LEak Detection (SLED) system to autonomously monitor pipelines for hazardous chemical spills. SLED leverages a visible and a thermal camera along with machine learning techniques to reliably detect the chemical fingerprint of small hazardous liquid leaks on surfaces typically found near pipelines (e.g. gravel, dirt, grass, concrete). SLED is able to detect small hazardous liquid leaks including crude oil, gasoline, diesel and mineral oil, and also is able to classify these different substances in real-time on different surfaces and in several different environmental conditions (e.g., lighting, temperature, etc.). SLED is able to operate fully unmanned and perform leak detection in less than five seconds.

This research is focused on the extension of the SLED technology to reliably detect crude oil leaks in water bodies using advanced imaging, feature extraction, and classifier techniques. The technology fuses input from the optical sensors in different combinations (visual, infrared) to identify unique features that provide a more reliable “fingerprint” crude oil slicks on water. Since false positives are a major obstacle in leak detection, the feature extraction techniques and classifier training methods focus not only on detecting crude oil slicks on water, but to also on identifying and rejecting a variety of non-leak events to substantially reduce false positive rates.

How can other operators put this into practice? The technology can be leveraged by operators as an oil-on-water detection system in critical areas where pipeline infrastructure is in the near vicinity of waterways or where outflow of various culverts needs to be monitored for the presence of hydrocarbons. Because the technology is designed for an aerial platform (e.g. drone), it can afford operators significant monitoring capabilities.

11:00 AM – Pipeline Leak Rate Estimation

Presenter: Mark Piazza, Colonial Pipeline Company

Description of the research: Pipeline design and integrity management programs are employed to develop and maintain reliable energy product pipelines. Pressure cycle induced fatigue is of concern for liquid pipelines because of its potential to produce a product releasing through wall crack. Being able to estimate the leakage rate or total release volume are important in evaluating through crack consequence, operational responses when incidents occur, and remedial action strategies and timelines. Estimates of leak rates can be used in pipeline system threat and risk assessment, evaluation of leak detection system sensitivity, development of emergency response plans and strategies, and post-event evaluation. Fracture mechanics techniques consider the response of crack-like features to applied loading, including estimation of crack mouth opening. Considering the differential of pressure across a pipe wall through crack the flow of fluid can be estimated. Full-scale testing to measure leak rates though dent and axial flaw induced fatigue cracks of differing lengths at a range of internal pressures and compare measured results to the analytical estimates. The test procedure grew cyclic internal pressure fatigue cracks on end-capped pipe samples and leak rates were measured at the through crack at constant pressures.

The results of this experimental trial illustrate that tight fatigue cracks resulted in a discontinuous relationship between leakage rate and pipe internal pressure. Measurable leakage did not occur at low pipe internal pressures and then increased in a nonlinear trend with pressure. These results illustrate that a liquid pipeline with a through wall fatigue crack operating at a low internal pressure, or one having taken a pressure reduction, can have low leakage rates. The data presented in this paper was used to estimate failure consequence.

How can other operators put this into practice? The data and results presented in this paper provide a basis for evaluating the performance of leakage rate estimation models used for pipeline fatigue cracks. These insights into leakage rate modeling tools and their ability to predict measured leak rates will support fatigue crack consequence evaluation. Operators will be able to select leak rate modelling tools with an understanding of their performance in support of risk and consequence modelling.

Being able to estimate the leakage rate or total release volume are important in evaluating through crack consequence, operational responses when incidents occur, and remedial action strategies and timelines. Estimates of leak rates can be used in pipeline system threat and risk assessment, evaluation of leak detection system sensitivity, development of emergency response plans and strategies, and post-event evaluation.

11:30 AM – Visualizing Buried Networks in Augmented Reality

Presenter Carine Lacroix, GRTgaz – RICE

Value to operators: Damage to structures is an important issue for network operators, especially in urban environments as the basement can be very crowded. One of the main issues for construction sites close to sensitive networks is the localization of underground utilities in order to avoid big damages.

In France, before works, it is mandatory to declare works to get the mapping of networks close to the intervention. The equivalent practice in US/Canada is the One Call System where all parties involved in pipeline operation share, on a single tool, necessary information prior to any work.

However, network plans are not often easy to analyze and then operators are confronted to difficulties as the reliability of data, heterogeneities of the plans…The aim of GRTgaz's Research and Innovation Center for Energy (RICE) Pipelines Department project is to visualize the underground in the most simple and efficient way thanks to a digital application which uses augmented reality (AR). AR has considerable benefits for underground utilities. Making visible what is beneath the ground is of major importance for asset management, construction safety and road management.

Description of the research: At GRTgaz RICE, many research activities focus on the third-party interference issues and especially utilities identification before construction activities.

In 2017, GRTgaz-RICE developed an application, ARCana, to visualize underground utilities in an experimental site, as a first step of AR opportunities investigations. The objective of this development was to identify the general process, critical issues and deliver a first demonstration for operators.

GRTgaz-RICE has a specific test area dedicated to works on detection/localization of underground utilities. In this 200 m2 area, pipelines of different materials (steel, poly-ethylene, iron cast, PVC) where buried, as well as service lines, electrical cables, markers, marker tapes, PE slabs at various depth. This test facility was divided in five areas backfilled with specific soils all representative of the French territory. Half of the surface was covered by asphalt to simulate urban sites.
During the construction of this laboratory, each buried item was geo positioned (XYZ positions) with a precision of 3 cm maximum.

For this application, the pipelines were modeled in accordance to their real aspect. For example, distribution pipelines were represented as a black cylinder with yellows stripes. The separation walls were modeled and textured too, in order to give to users, the illusion of depth.

How can other operators put this into practice? Third-party interferences is one of major issues of all underground utilities operators. The first development made by RICE GRTgaz aimed to visualize underground utilities buried in a specific test facility. An operator can use these results to improve detection/mapping tools and exploring AR technology through different use cases and applications. Indeed, the previous work made by GRTGaz RICE reveals perspectives of improvement for each step of the data processing and display to switch from a lab application to a real site.

Data reliability of network maps is of the major importance. As the application displays the raw data with no additional treatment, their quality and reliability must be ensured. The operator can use detection technologies to confirm or unvalidate the utilities position onsite. One of the perspectives may be using AR as a new interface for detection tools. A comparison between the GIS data and the detection measurement would provide useful information before digging.

Geopositioning system is a large improvement area. From our first experience with AR Cana, we can easily conclude that markers-based on geopositioning is not a realistic method for an industrial deployment on the entire gas network for economics and technical reasons.

Consequently, the next development will include a GPS RTK system with a high-level of precision. However, GPS system is not considered as ergonomic enough for user-friendly application, especially for HMD (Head Mounted Display) applications (the user sees virtual objects through glasses).

1:00 PM – CONOPs for LiDAR Operationalization for ROW Monitoring

Presenter: Francois Rongere, PG&E

Value to Operators: LiDAR is extremely capable technology and can enhance multiple efforts on safety, reliability, and integrity. However, LiDAR is a complex subject and operators can benefit from better understanding how to effectively deploy it. This presentation will provide guidance to operators, based on lessons learned by PG&E and Enview, on how to best deploy and operationalize LiDAR while minimizing costs.

Description of the research: This work opportunistically leverages PG&E's deployment of airborne LiDAR. Many lessons are being learned about how to deploy and operationalize LiDAR for pipeline integrity and ROW surveillance. PG&E will conduct recurring data collection flights over areas of interest to be determined. Additionally, PG&E will provide data to support topographic/depth of cover change comparison, as well as in-kind activity/time to finalize the Final Report. Enview will process and analyze data from PG&E; draft CONOPs from lessons learned while supporting PG&E's operationalization of LiDAR, as well as write the Final Report.

How can other operators put this into practice? The results of this work are a CONOPs for deployment of LiDAR and shall contain guidance on a variety of factors including, but not limited to: cost-optimal LiDAR resolution and accuracy, sensor requirements and selection, frequency of data collection, resolution of co-collected imagery, lessons learned on how to interpret data, and visualizations of sample findings.

1:30 PM – Evaluation of Current ROW Threat Monitoring, Application, and Analysis Technology Project Update

Presenter: Paul Adlakha, LOOKNorth, C-CORE

Value to Operators: This project is a study to provide operators with research on satellite systems and how they may address specified pipeline threats. The output is recommendations on satellite monitoring programs that can address those threats and the extent to which they are cost effective.

The benefits include a common terminology/understanding of the threats that concern operators and how satellite technologies can help to improve the monitoring, response, and potential mitigation of those threats. This project includes the various 3rd party damage threats, several types of hazards, and potential leak detection.

The current and near-launch satellite capabilities are mapped against the various potential threats, and operators are provided with a guide on which satellite systems provide the best value against specific threats. The project studies the value of recent 'free and open' missions, the traditional commercial missions, and the emergence of several venture capital funded smallsat missions that are proving to be disruptive to the benefit of the industry.

Modeling and simulation of scenarios on a selected pipeline system highlight gaps in satellite technology capabilities (sensor or monitoring coverage) to provide operators with a clear understanding of the limitations of the current missions and where other technologies may provide a better solution.
A review of current suppliers is also presented.

In addition to the RFP Scope of Work, the primary input into developing the satellite approaches is a series of interviews with operators, and research from previous studies in this area.

Description of the research: Develop a consistent list of current threats from operators: e.g. 3rd party activity, 3rd party damage, hazards, and leak detection.

Determine current means of data acquisition and analysis for each threat.

Determine the application of satellite data for each threat.

Recommend satellite monitoring approaches for the various threats and highlight their strengths and weaknesses. Determine gaps in application of satellite data that must be filled by other means.

Identify listing of companies with current and near-term technology that can support threat analysis. These include providers of satellite data and value-added services.

Provide recommendations to stay current on satellite technology advances, and a case study program to validate some of the findings in this phase.

Ultimately operators should gain an understanding of which satellite approaches could provide value to their own pipeline systems.

How can other operators put this into practice? Operators will be able to use the information from this study to compare the value of satellite-based monitoring (cost and information content) against current approaches. Access to appropriate satellite solutions will be recommended so that operators can access pre-screened solutions. Operator participation in a follow-on multi-operator validation phase can reduce the learning curve associated with technology implementation on their own pipeline system.

2:00 PM – Obstacle Detecting Technology for Horizontal Drilling

Presenter: Carine Lacroix, GRTgaz – RICE

Value to Operators: Horizontal directional drilling (HDD) is a means of installing underground pipes and cables without digging trenches. The method offers numerous advantages over traditional approaches, but requires care, when used in crowded urban areas, because of the risk of damage to existing buried infrastructure. This is mainly due to uncertainty of the precise location of underground utilities and other obstacles in the path of the drill head. The European project ORFEUS gathered 11 partners and was enlarged to to North America through support from PG&E, Gas Technology Institute (GTI) and Operations Technology Development (OTD); allowing for the development of a horizontal directional drilling machine with "look ahead" technology; radar incorporated into the head of the drilling head to detect and warn the operator of the obstacles during the drilling operation.

Description of the research: ORFEUS Phase 1 project occurred between 2005 and 2009. During this period, the feasibility of radars incorporated in a drill head to complete HDD was demonstrated. The most important result of this first project was the construction of a revolutionary drill head. Having completed the successful development of the new system, the next phases of the ORFEUS project focused on industrial integration and field demonstrations.

ORFEUS Phase 2 included technical improvements of the system, in particular:

- a novel radar system
- a gyroscope roll angle sensor which works under arduous shock and vibration conditions

- a drill rod connector system for carrying power and data in the presence of bentonite (drilling mud), and the modification of a standard drilling rig to accept the new operational system.

Modifications have also been required on the standard drill equipment, including the addition of a slip ring system to allow electric power and data to be transferred from the rotating drill string to the operator on the stationary drill rig.

For end-users, the most important part of the ORFEUS Phase 2 was to demonstrate the operational viability of the system and how it could be useful at actual field sites. The most important aspect to be tested was the real time acquisition software and post processing analysis.

How can other operators put this into practice? Field trials carried out in Germany, France, Slovenia and United States contributed to an assessment of the risks, and confirmed operational viability and performance of the ORFEUS prototype system. This demonstration phase also helped to assess the environmental benefits and to increase confidence, awareness and uptake of this new technology by public authorities, industry, standardization bodies, and the general public.
The ORFEUS bore head is a prototype which could be used with every drilling machine, with only a few modifications required. It is also important to note that a PAS (Publicly Available Standard) has been written as part of the project.

During the field trials the system was found capable of detecting object (pipes, cables, walls, etc.) in the proximity of the drilling head, up to a distance of approximately 50 cm, both ahead and to the side. A dedicated real-time software was developed and tested; it is capable of displaying the positions of the detected targets in a 3-D image.

Further developments of the technology will improve the real-time visualization (e.g. synthetic results after target detection) and the generation of a warning alarm when a risk of strike is detected.
Most of the engineering problems have been overcome, and the task ahead is to refine the technology to produce a commercially viable system.

Future development activities are being planned and intended to raise the Technology Readiness Level to 9 through a US and European funding collaboration project. This Phase of the project will be lead by RICE and GTI with other potential end users, PHMSA and OTD technical and financial support in order to comply with utility requirements worldwide.

2:30 PM – Remote Monitoring of Geohazards for 800+ Kilometers of Pipeline and Right-of-Way Protection in Permafrost, Snow and Vegetation Using Radar Satellite Interferometry (InSAR)

Presenter: Kris Covey, 3vGeomatics Inc. and Shin-ichi Sobue, Japan Aerospace Exploration Agency (JAXA)

Value to Operators: The research demonstrates how InSAR can be successfully deployed for remote sensing of geohazard risk along very long sections of pipeline in challenging, hard to access locations that include permafrost, snow, and vegetation. The subject pipelines traverse slopes that may contain geohazards in some locations. It is difficult and expensive to install ground instrumentation across such large expanses, especially given the remote location. InSAR is being used as a tool to give the operator actionable intelligence on the geohazards that can impact the integrity of their line across very large geographic areas. The presented research will allow PRCI members to better understand the viability and limitations of InSAR from an operational standpoint in applications and locations that are relevant to their network. The presentation will also include a technical and operational overview of the radar satellite used in this research project, ALOS-2, by the Japan Aerospace Exploration Agency's (JAXA) lead Project Manager Shin-ichi Sobue. This will be a rare opportunity for PRCI members to hear and ask questions about ALOS-2, and its unique advantages as the only radar satellite capable of being used for InSAR monitoring in vegetated areas, directly from the person at JAXA responsible for

its operation. Mr. Sobue-san will also discuss JAXA's newest radar satellite, ALOS-4, with regard to its design specifications, future launch date, how its images will correlate with those acquired by ALOS-2, and the satellite's continued suitability for InSAR monitoring in vegetated areas.

Description of the research: The research involves InSAR analyses of historical radar images acquired by JAXA's ALOS-1 radar satellite from 2006 to 2011, and newly acquired images from JAXA's ALOS-2 satellite (2014 – present). The images, at 70km x 70km each, for both ALOS-1 and ALOS-2 cover the entire 800+ kilometer historically from 2006 to 2011 and 350+ kilometer section of pipeline from 2014 to present day in a remote area that has permafrost, snow, and vegetation. The area also contains a facility containing assets from multiple pipeline operators. The areas are known to have geohazards. In separate but related work, 3vGeomatics has shown how a historical InSAR analysis can identify significant slope movement. Our continued research using contemporary radar satellite images of the subject pipeline will align available historic data and InSAR analyses with ongoing yearlong monitoring to identify the extent and magnitude of displacement over time and the potential development of slope creep into faster moving landslides.

How can other operators put this into practice? Based on the results of the analyses, 3vG will provide an outline on how an operator can utilize InSAR for ongoing monitoring of their pipeline networks. InSAR provides historical and contemporary ground displacement data to assist pipeline operators in:

- Identifying unknown, and monitoring known, areas of displacement along pipeline networks including determining the size, extent, rate, and potential changes in rate of moving land masses
- Mitigating risk by incorporating historic and ongoing displacement monitoring into pipeline right of way maintenance and inspection programs
- Identifying critical locations for targeted use of ground-based instruments
- Using InSAR to verify and align ground movement with other data sources
- Determining the effectiveness of historic landslide mitigation practices with contemporary displacement data
- Utilizing InSAR historic data to aid with the routing of new pipeline construction

Wednesday, March 6, 2019 – TRACK TWO: WELDING

8:00 AM – Enhanced Girth Weld Performance for Newly Constructed Grade X70 Pipelines

Presenter: Robin Gordon, Microalloying International Inc.

Value to Operators: This project has been performed in two (2) phases. Phase 1 is complete and produced preliminary guidelines that focused on line pipe specifications, girth weld development and qualification, and pipeline construction practices in order to ensure adequate strain capacity of girth welds. Through finite element modeling, mechanical and materials testing, and data analytics, the results from Phase 2 will provide knowledge required to understand the root-cause of why girth welds can fail at relatively low strain capacity; specific consideration for heat affected zone softening and girth weld undermatching. Phase 2 is scheduled to be complete by end of 2019 and will provide pipeline operators with the necessary procedures to mitigate low-strain girth weld failures that may occur in X70 line pipe through appropriate line pipe specifications, mechanical property testing, and/or girth weld procedure qualifications.
The overall objective of this JIP is develop an understanding of why certain girth weld failures have occurred under relatively low-strain conditions, and then to apply these learnings in order to develop procedures that are expected to mitigate future girth weld failures. The recent increase in Grade X70 girth weld failures is a major concern to the pipeline industry and begs this question: What has changed? While X-70 line pipe has been used for years, there is a concern that something has changed, either with the line pipe materials and/or the girth weld procedures, that has contributed to girth weld failures under certain conditions.

Description of the research: The results of this research will provide guidelines that will enhance the performance and strain capacity of girth welds used in newly constructed X70 pipelines without compromising other important line pipe requirements. The Guidelines will cover line pipe and girth welding:

- Line pipe production, chemistry, mechanical properties
- Extent and effect of heat-affected zone softening
- Girth weld properties, procedures and consumables.

How can other operators put this into practice? Operators will use the results of this project for capital construction projects where line pipe and girth weld specifications are produced and provided to potential vendors that will provide necessary materials and services required.

8:30 AM – Mechanical Properties of Vintage Girth Welds and Their Implications on Performance

Presenter: Dan Jia, CRES

Value to Operators: Vintage pipelines, in the context of this paper refer to to pipelines built before approximately 1970, account for a large portion of the energy pipeline systems in North America. Integrity assessment of these pipelines can sometimes present challenges due to incomplete records and lack of material property data. When test data of the welds of interest are not available, the values of the material properties required for assessment are typically taken from experience-based conservative estimates. Such estimates can be overly conservative, potentially leading to unnecessary remedial actions.

Before the start of this project, very little useful and relevant mechanical property data of vintage girth welds were available. When available, the data were typically collected in failure investigations. The scope, type, and record-keeping

of the collected data were often inadequate for use in future assessment. Having isolated bits of data available, without understanding the conditions of the data generation, made the data difficult to use for predictive decision-making.

The outcome of this research allows the operators to make informed decision in routine maintenance activities and responses to infrequent but high-consequence events, like ground movement. Without the information generated in this research, unnecessary repairs or replacement might be done or true risk factors are not clearly identified.

Description of the research: This research was aimed to characterize material properties and flaw characteristics of vintage girth welds. The 10 girth welds were fabricated in 1940s to 1960s. The pipes ranged from Grade B to X52 with wall thicknesses in a range of 0.281" to 0.375" and the outer diameters varied from 20" to 36". The seam welds of these vintage pipes were ERW, seamless, flashed weld, DSAW, EFW, and SAWL.

The material property data include (1) pipes tensile properties, (2) deposited weld metal tensile properties, (3) Charpy impact transition curves of specimens with notches in the heat-affected zone and weld centerline. In addition, cross-weld tensile specimens were tested and analyzed.

The tensile testing of pipes indicated that the yield strength of the vintage pipes was higher than the specified minimum yield strength, sometimes by a significant margin. The actual pipe strength within the same grade tended to have greater impact on girth weld strength mismatch level than the weld metal strength.

In most cases, the vintage girth welds had a large cap reinforcement in both height and width. Although some of the girth welds had weld strength undermatching, the cross-weld tensile specimens did not fail in the weld region due to the beneficial effects of cap reinforcement.

The weld strength mismatch and cap reinforcement had a significant impact on the tolerance to longitudinal stresses and strains. Welds without high levels of strength undermatching and with wide cap reinforcement had excellent tolerance to longitudinal stress and strains, even in the presence of large weld flaws.

The Charpy transition curves indicated that the weld metal would behave in a ductile manner under normal service conditions of buried pipelines.

How can other operators put this into practice? The basic mechanical properties and flaw characteristics obtained in this research can serve as direct input data to the girth weld tensile strain capacity prediction tool developed under PRCI project SIA-1-7. In addition, the data can be used to develop alternative X-ray criteria using fitness for service principles. The alternative X-ray criteria should reduce unnecessary repairs and cutout.

9:00 AM – Fracture Resistance Testing of Dissimilar Girth Welds Using SE(T) Specimens

Presenters: Eduardo Hippert, Petrobras & Claudio Ruggieri, University of São Paulo, Brazil

Value to Operators: Structural integrity assessments of pipe girth welds remain essential in fitness-for-service analyses of oil and gas transmission pipelines, including onshore and offshore facilities. Typical welding processes introduce strong thermal cycles and inhomogeneous residual stresses in the pipe girth weld metal and surrounding region (including the heat affected zone - HAZ) which often deteriorate the metallurgical quality and potentially lower the fracture resistance of the weld joint (as compared with the base plate material). These features largely increase the likelihood of failure from the crack propagation of an undetected weld defect and, at the same time, impact rather strongly flaw acceptance criteria

for girth welds. Consequently, accurate measurements of fracture resistance properties, including crack growth resistance ( ) curves of the girth weld material, become essential in defect assessment (ECA) and fitness-for-service (FFS) procedures of the weldment region (which also includes the heat affected zone). Current fracture mechanics-based approaches to specify acceptable flaw sizes for pipe girth welds rely on direct applications of J-resistance data based on the use of single edge notch tension specimens (often termed SE(T) or SENT crack configurations) to measure experimental R-curves more applicable to high pressure piping systems and pipe girth welds subjected to predominantly bend loading. Recent applications of SE(T) fracture specimens to characterize crack growth resistance properties in pipeline steels have been effective in providing larger flaw tolerances while, at the same time, reducing the otherwise excessive conservatism which arises when measuring the material's fracture toughness based on high constraint, deeply-cracked, single edge notch bend SE(B) (also termed SENB crack configuration) or compact tension C(T) specimens. While higher conservatism in ECA and FFS analysis represents an extra factor of safety, excessive pessimism in defect assessments can lead to unwarranted repairs or replacement of in-service pipelines at great operational costs.

Description of the research: This work presents an experimental investigation of the ductile tearing properties for a girth weld of a typical C-Mn pipe internally clad with a nickel-chromium corrosion resistant alloy (CRA) using crack growth resistance ( ) curves. Here, the material of the external pipe is a typical API 5L Grade X65 pipeline steel with high yield stress and relatively low hardening properties whereas the inner clad layer is made of ASTM UNS N06625 Alloy 625 with lower yield stress and high hardening. Conducted as part of a collaborative research program between Petrobras and University of São Paulo (USP), testing of the pipeline girth weld employed side-grooved, clamped SE(T) specimens with a weld centerline notch to determine the crack growth resistance curves based upon the unloading compliance (UC) method using a single specimen technique and load-displacement records. The resistance curves are determined based on the procedure developed by Petrobras and University of São Paulo (USP) to evaluate crack growth resistance data using estimation equations for and CTOD versus. The analyses then consider evaluation of -resistance data from newly developed results to estimate and from 3-D finite element computations of weld centerline notched SE(T) specimens incorporating the clad layer and the experimental stress-strain response of the weldment. Finally, we compare the crack growth resistance curves defined in terms of CTOD- data for which the CTOD is determined on the basis of -CTOD relationships and the double clip gage (DCG) technique. These results are further compared with crack growth resistance data derived from a digital image correlation (DIC) method to measure the CTOD directly from the deformed crack flank for the extending crack. This exploratory experimental characterization provides additional toughness data which serve to evaluate the effectiveness of current procedures in determining experimentally measured crack growth resistance curves for this class of material, including dissimilar girth welds.

How can other operators put this into practice? While now utilized effectively in fracture testing of pipeline girth welds, a unified and broader SE(T) testing procedure covering either homogeneous materials and weldments, including dissimilar girth welds, is still lacking. Despite the recently introduced BS 8571 standard, a number of key issues associated with the test methodology raise potential concerns about the significance and qualification of measured crack growth resistance curves which, in turn, may potentially affect tolerable defect sizes obtained from engineering critical assessment (ECA) procedures. The present work can provide pipeline operators with valuable insight and further understanding of the crack growth resistance testing applicable to pipe girth welds while, at the same time, supporting recent standardization efforts for fracture testing of pipeline girth welds.

9:30 AM – Tensile Strain Capacity of Girth Welds

Presenter: Bo Wang, CRES

Value to Operators: Integrity assessment of vintage pipelines sometimes is necessary after a ground movement event and/or the discovery of weld anomalies. Applying fitness-for-service (FFS) principles to the integrity assessment of vintage girth welds is one of the options being used by the industry and regulators in IVP (integrity verification process). The most widely used assessment procedures, such as API 1104 Annex A and API 579/ASME FFS-1, were developed principally for materials under nominally elastic conditions. The accuracy of those procedures deteriorates quickly when the applied nominal stress is close to yield strength or even greater. In the case of longitudinal loads imposed by ground movement, the detectable strains by the most-widely- used methods can put the applied stress close or beyond the yield strength. The above- mentioned assessment procedures can't be applied or they would produce exceedingly conservative results, leading to unnecessary repairs or cutouts.

The objective of this research was to develop a tensile strain capacity (TSC) estimation tool for vintage pipelines. The ability to assess the TSC of vintage girth welds enables operators to prioritize maintenance activities and reduce unnecessary remediation work. The primary benefits are to help operators: (1) reduce unnecessary digs, (2) make remediation decisions with confidence, (3) justify maintenance decisions to regulators, and (4) allow better integration and use of ILI and other inspection results.

Description of the research: In Phase I of this research, a large amount of finite element analyses (FEA) were conducted to determine the crack-driving force relations by taking account of some salient features of vintage girth welds, such as large weld cap, thin pipe wall thickness, and weld strength mismatch. The TSC of vintage girth welds were determined from the crack-driving force relations and the apparent toughness based on an initiation-control limit state. A TSC estimation tool was developed to facilitate the calculation of TSC. The tool takes user inputs, such as the geometry and material properties of pipe and weld, flaw dimensions, and pipeline pressure, and provides estimated TSC. For the inputs that might not have readily available values, recommended values are provided. This tool allows the evaluation of the impact of various input parameters on TSC.

In Phase II, small- and large-scale experimental tests were conducted on selected vintage girth welds. The small-scale tests include pipe tensile, pipe chemical composition, weld macros, and weld microhardness maps. The large-scale tests include eight curved wide plate (CWP) tests. The measured TSCs from CWP tests were compared to the estimated TSCs from the tool. After taking into account of the customary safety factor, the TSCs from seven of the eight tests were higher than that predicted by the tool, indicating the tool produced conservative TSC estimation. One of the CWP specimens had TSC lower than that from tool prediction. This specimen had large pre-existing weld flaws that were not reported by pre-test X-ray. In addition, the specimen had a high level of weld strength undermatching.

Although more testing is needed to further validate the TSC estimation tool, the data so far indicate the tool provides correct trends in TSC and conservative TSC estimation.

How can other operators put this into practice? By taking the material property and flaw characteristic inputs from PRCI project SIA-1-4, the TSC estimation tool developed in this research provides valuable information on the strain capacity of vintage girth welds. This strain capacity can be compared with strain demand obtained from ILI IMU runs. This comparison provides direct indication of the integrity of the girth welds.

This TSC estimation tool can be used system-wide for screening of at-risk girth welds. It can also be used to perform case-specific assessment after a loading event, such as ground movement.

Wednesday, March 6, 2019 – TRACK TWO: DESIGN, MATERIALS & CONSTRUCTION

10:30 AM – Significance of Automatic Pipe Dimension Measurement of Line Pipe for Deep Offshore Pipe Lines *(moved from Subsea track)*

Presenter: T.S. Kathayat, Welspun

Value to Operators: The end dimension of a line pipe, like outer & inner diameter and out-of-roundness play a huge role in the fitment of pipes in their pipeline laying stage. This automated measurement system ensures to give very accurate dimensional data, with astounding resolution.

In special applications like offshore pipeline projects, it is very crucial for the pipes to have very close dimensional tolerances, for efficient and timely pipe-to-pipe joining. The dimensional parameters of pipe end are the deciding factors of timely and successful completion of such a project. Repairs at later stages of the project, due to poor circumferential welding, become a cumbersome task, due to the extreme locations in which the pipeline is laid. From the dimensional data of pipe ends of the particular pipe lot, the pipe laying agency can easily decide on a laying sequence for the best possible weld joint preparation, based on the automatic selection of near congruent ends' geometry, ensuring a clean weld with excellent weld quality.

Laying operators can have a peace-of-mind as they have all the required data available to minimize their laying time and gain huge monetary benefits.

Description of the research: The system for the automated pipe measurement is the result of laborious analysis and development of some very specific dimensional features, in conjunction with the system OEM. Research was done to understand the requirements to be fulfilled of international specifications and clients. Methods were then established which would comply with these standards and provide measurement data in the desired format. The pinnacle of the campaign was the installation and stabilization of the system. Various teething issues were technically understood and systematically solved during this transition to automated pipe measurements.

The research then continues on to the analysis of the accuracy of the measured parameters from the system. Repeatability and reproducibility of the system are measured and validated, after rigorous trials, comprising of variety of scenarios faced on the shop-floor.

Automated Pipe Dimension Measurement System (APDMS), which measures a total of 19 dimensional parameters after real-time geometrical & trigonometrical calculations, using parametric data from 72 measurement laser scanners & sensors. A pipe that needs at least 45 minutes to measure all dimensional parameters manually, by 2 men and almost 25 instruments & accessories, is measured in 2.5 minutes by APDMS with mind-boggling resolution and accuracy.

How can other operators put this into practice? A pipe manufacturer can replicate this system for reliable and accurate pipe measurements, which can then be passed on to the laying contractor for a smooth and effortless process. There can be no practical comparison between manual and automated measurements due to a variety of dependent factors, like man and method.

Other players can analyze the accuracy levels obtained by this system, for more than 60,000 pipes measured since its installation, and understand that there is no better alternative than this system, especially for off-shore pipeline projects where the dimensional accuracy is the key.

11:00 AM – EPRG Approach to Assess Avoidance of Brittle Fracture in Presence of Ductile Initiation in DWT Tests
Presenter: Marion Erdelen-Peppler, European Pipeline Research Group

Value to Operators: DWTT is an essential test to avoid brittle crack propagation in gas pipelines, which is the pre-requisite to apply the methods described to control ductile fracture propagation that are laid out in the applicable line pipe standards. There is some uncertainty in interpreting the results of DWT tests that do not meet the requirement of brittle initiation as per API 5L3, a phenomenon referred to as inverse fracture. While the occurrence of inverse fracture is acknowledged in API 5L3, the tests are considered invalid and there is no guidance as to how to assess the results. The lack of data confirming whether DWT tests with ductile initiation reproduce the transition temperature of the pipe leave the risk that such material may not be properly described in terms of toughness and may not be suitable for operation at a specific temperature. Clarity is needed to ensure pipeline safety for material showing inverse fracture.

Description of the research: EPRG has conducted West Jefferson (WJ) tests alongside DWT tests with different notch types that may have the potential to eliminate the ductile initiation. The comparison of transitional behavior between DWT t and pipe tests is the most reliable method to understand the implications of inverse fracture. The test results showed that ductile initiation could not be reliably suppressed, regardless of the notch type. On the other hand, if the material did show both inverse and regular behavior at a certain temperature, the difference in terms of shear area was marginal. The comparison of DWT and WJ results indicated that DWT tests with inverse fracture were suitable to predict the pipe transition. The results have been assessed such that the reason for stipulating the requirement, which is documented in the original reports produced by the Battelle Institute and British Gas, has been addressed and consistency to the old results in ensured. On basis of the investigation, EPRG plans to issue guidelines on interpretation of inverse DWTT results that will be presented to the API working group.

How can other operators put this into practice? As it is planned to issue guidelines and approach standardization bodies, the results will be made available to the all operators.

11:30 AM – Evaluation of Cracked In-service Welded 4” Stub End with LOR Flange

Presenter: Otto Jan Huising, N.V. Nederlandse Gasunie

Value to Operators: Sharing an investigation of a failure to an in-service welded stub end with LOR flange. To support, based on the results of the investigation, the safety and rigidity of the in-service welding practices as developed based on PRCI research methods.

Description of the research: The failure of a 4”stub end welded to an 12”pipeline was researched. The stub end was complete ripped out of the pipe body during demolition works. No gas was released since the pipeline was out of service. The fracture was metallographically examined and research was performed on:

- In-service welding practice and subsequent loads of hot tapping
- Pressure variations causing fatigue load
- Flow variations causing flow induced vibrations
- Practice of demolition works.

How can other operators put this into practice? Benefit from the support documentation of safe in-service welding practices when developed on PRCI research. Learn from the results of research from the items on pressure variations, flow induced vibration and demolition practices.

12:00 PM – Soil-pipe Interaction in Muskeg Soils for Design of Buried Energy Pipelines

Presenter: Dharma Wijewickreme, University of British Columbia

Value to Operators: The research work is mainly contributing to real-life industry problem of protecting buried oil and gas pipelines in located muskeg/organic soils (by reducing soil loads on pipelines). The work is undertaken using the Advanced Soil-Pipe Interaction Research (ASPIReTM) facility at the Pipeline Integirty Institute (PII), University of British Columbia, Vancouver, B.C., Canada. The research is funded by the Natural Sciences and Engineering Research Council of Canada (NSERC). In the PRCI (2009) guidelines, for constructing pipelines in areas subject to geotechnical hazards, subsidence occurring due to drainage and associated potential for upheaval buckling of buried pipelines is considered a valid concern. Outcomes bring significant value to pipeline operators through the following:

- Improved understanding of how soil-pipe interaction takes place on pipelines buried in muskeg (organic) soils.
- Generate new "numerical soil-springs" for use in PRCI guidelines when calculating soil restraints on pipelines buried in muskeg soils.
- Define new filed soil characterization methods to derive soil parameters to derive "numerical soil-springs" for pipelines buried in muskeg soils.

In addition, the industry will be informed on the availability to investigate project-specific issues using the UBC-ASPIReTM Facility at UBC. The UBC-ASPIReTM research work that has been completed so far to assess alternate backfill materials around pipes, and the soil loads transferred to multiple buried parallel line systems in real-life major engineering projects are good examples in this regard.

Description of the research: Over 1.5M km2 of Canadian landscape is covered with muskeg, which is soft in stiffness and weak in strength, and many oil and gas pipelines cross these soils. Thermal changes due to operational and environmental reasons have been recognized as a threat to the structural integrity and safety of buried oil and gas pipeline systems in organic soils such as muskeg. In particular, thermally-induced large deformations tend to cause buckling and potential integrity concerns of pipelines due to the low restraint between the pipe and the surrounding soil at locations of pipe direction change (i.e., at bends, elbows, etc.). As indicated in PRCI (2009) guidelines, for constructing pipelines in areas subject to geotechnical hazards, subsidence occurring due to drainage and associated upheaval buckling of buried pipelines in organic soils is another valid concern.

Most of the current design approaches (e.g., PRCI 2009; ASCE 1984) have been developed to address the soil pipe interaction of pipelines buried in typical sand/clay-like soils. Engineers encounter significant challenges in directly applying these approaches for the assessment of the structural integrity of buried pipelines located in muskeg (organic) soils. This is primarily due to the lack of understanding of the mechanical behavior of organic soils and their significant variability. As such, there is a need to provide specific guidance to the engineer for the assessment of pipelines buried in muskeg soils.

For these reasons, a research program has been undertaken to: (i) develop optimal approaches to characterize the variable mechanical response of muskeg soils; (ii) develop representative "soil springs" to simulate the soil-pipe interaction for pipes buried in muskeg soils in a cost-effective way; (iii) verify/calibrate the developed soil-pipe interaction model to justify its suitability for engineering evaluations. This presentation is intended to summarize the key work undertaken and some initial results from the investigations.

How can other operators put this into practice? The findings from this research work can be readily applied to practice in cases to protect buried oil and gas pipelines in muskeg terrain. The outcomes form research can be translated to PRCI guidelines with respect to:

- Guidance on conducting geotechnical investigations for design of pipelines in muskeg terrain;
- Methods to estimate soil restraints (soil springs) for numerical analysis of pipelines in muskeg areas; and
- Developing methods to reduce soil loads on pipelines in muskeg areas.

In an overall sense, improvements on the soil-pipe interaction approaches should translate to reducing the risk of buried pipeline damage due to ground movements in areas of organic soils. The pipeline industry will be able to apply the methodologies in a project-specific basis.

12:30 PM – Composite Crack Reinforcement

Presenter: Chris Alexander, ADV Integrity, Inc.

Value to Operators: For the better part of the past 25 years the transmission industry has contributed significantly to the expanded use of composite materials as a means for reinforcing pipelines. The early uses of composite materials primarily involved the reinforcement of corrosion features; however, over the past decade composite materials have been used to reinforce an array features and anomalies including dents, mechanical damage, fittings, branch connections, wrinkle bends, vintage girth and seam welds, and even crack-like defects. To support the innovative implementation and use of composite materials, significant financial and in-kind contributions have been made by PRCI, individual operators, composite repair companies, and even regulatory agencies.

Description of the research: Over the past five years both pipeline operators and composite repair manufacturers have explored the use of composite materials for reinforcing planar defects and crack-like features. Although there is undoubtedly more work to be done, the results have been promising. Carbon-epoxy composite technologies have demonstrated through full-scale burst and pressure cycle testing the ability to retard, and in some cases stop, the growth of cracks. This paper provides a synopsis of results to date, related full-scale testing work, a proposed design methodology, and a discussion on current knowledge gaps that need to be addressed in future research efforts.

How can other operators put this into practice? As with the use of composite in reinforcing corrosion, dents, mechanical damage, bends, branch connections, fittings, wrinkle bends, and planar defects, the expanded use of composite materials to the reinforcement of crack-like defects is significant and important to the pipeline industry. Composite materials are an economic alternative to the installation of conventional steel sleeves, are able to accommodate unusual pipe geometries (including ovality), and offer the added safety in not having to weld. Continued research is required to achieve widespread usage of composites in reinforcing crack-like defects. The contents of this paper will foster future interest in research supporting this innovative application.

Wednesday, March 6, 2019 – TRACK TWO: SUBSEA

2:00 PM – Local Hard Zone Formation in Sour Service Pipeline Steels

Presenter: Douglas P. Fairchild, ExxonMobil Upstream Engineering

Value to Operators: Local hard zones in large diameter pipe have been identified as the cause of the Kashagan pipelines failure, the replacement of which is estimated to cost $3.6B [1, 2]. This challenge is generating much attention in the industry and is the motivation behind several current PRCI projects [SSC 2-14, MAT-9-1, NDE-4-11]. This presentation will provide a description of how hard zones form in pipeline steels. Some mechanisms have been known for some time, while at least one mechanism is new and deserves increased attention by the industry.

Description of the research: Intensive metallurgical study and review of common steel processing techniques has enabled a detailed understanding of a new hard zone formation mechanism in Thermomechanical Control Processed (TMCP) pipe. This presentation will explain how TMCP steels, previously thought to have extremely low hardenability, can actually form hard zones at the plate surface during TMCP processing. These hard zones are thinner than a human hair and can be sporadic in their frequency and location. Nevertheless, these hard zones can cause pipeline failure when exposed to sour fluids. There are currently no validated industry standard inspection methods that can be used to find these hard zones.

How can other operators put this into practice? By understanding the fundamental science of hard zone formation, operators can formulate approaches to qualify pipeline steels. Basic understanding can help enable the development of inspection technologies capable of identifying hard zones. Other approaches to this challenge, such as the use of sour fracture mechanics, may also prove to be useful.

2:30 PM – Flexible Riser Life Extension Using Advanced Inspection and Analysis

Presenter: Arya Majed, INTECSEA

Value to Operators: Assessing the condition of a flexible riser as it approaches the end of its design life poses both technical and practical challenges. Assessing degradation of the critical tensile armour wire layer has been limited by the ability of the inspection technology to penetrate the outer sheath and detect defects in the tensile armour wires. Analysis of the fatigue response of the tensile armour wires has been limited by computational efficiency of Finite Element analysis tools, which have restricted current analysis framework to short duration static loading (regular wave). In addition, given the multi-layer composite structure of flexible risers, the overall integrity requires complex understanding of the condition of each layer and the interaction between layers.

The FlexIQ solution combines leading edge inspection and analysis capability to accurately model the fatigue response of ageing tensile armour wires. Embedded in a layer by layer risk based assessment in line with API17N a robust structure approach to life extension is achieved that can be aligned with company risk management procedures. FlexIQ approach allows elimination of assumptions and simplifications, leading to reduced uncertainties and risk in the fatigue life prediction.

Description of the research: FlexIQ combines the two proprietary technologies: MEC-FIT™ inspection technique from Innospection and FLEXAS™ numerical solver from INTECSEA which allows high-resolution stochastic fatigue life to be captured based on realistic conditions. Reducing uncertainty in the design calculations enables operators to continue operating their assets safely and with improved confidence.

MEC-FIT™ has been used on rigid system and proven in laboratory and field testing environments on flexible risers to be confident that defect interpretation of the eddy current signals from the tool can be reproduced. Using external scanning, the technology can detect in 2 (up to 3) layers of corrosion (pitting/general), cracking, wire misalignment / gaps. It is also possible to scan <37° wire: in axial direction and >37° wire: in circumferential direction.

FLEXAS™ uses a simulation-based approach to compute the flexible's wire stress time-histories to irregular wave inputs. The approach enables computationally efficient simulations of the flexible's detailed finite element model. In this way, the full kinematics of the wires is captured by the simulations and in addition, geometric defects revealed from the inspection can be incorporated in the model allowing accurate fatigue life prediction.

The validation of the NDS approach involved both numerical benchmarking and experimental validations. One hour long irregular wave global tension/curvature time-histories were utilized to drive a 10-pitch long local model of the hang-off. The local model was simulated for 24 irregular wave cases and stress time-histories, at the corners of 16 inner and 16 outer armour wire locations, extracted. The stress time-histories were rain flow counted and wire fatigue spectra generated. For the configuration studied, comparison of the wire fatigue spectra for the irregular wave wire stresses showed a 7x increase in predicted fatigue life relative to the regular wave approach executed on the same local model.

How can other operators put this into practice? FlexIQ has established a step change for industry technology and has been recently successfully deployed on two offloading risers in West Africa with a total inspection length of 2.5km. This paper demonstrates the success of combining MEC-FIT™ and FLEXAS™ in a risk-based approach to real operational situations in field environments.

Field experience on how FlexIQ has been used to re-evaluate the design life and determine the suitability for life extension of the risers will be presented.
Deployment of the inspection tool from the vessel avoided the need for ROV support or additional support vessels, cleaning of the riser was achieved prior to inspection and challenges associated with riser clashing were resolved to enable the longest MEC-FIT™ inspection length to date to be achieved.

Interpretation of inspection data enables the inspection team to provide accurate input to the prepared riser hang off models to enable FLEXAS™ simulation of tensile armour response.

Collection and interpretation of historic operating and inspection data enable a robust risk-based assessment of current condition and the definition of future inspection and monitoring requirements to be defined in an integrity management plan.

The analysis predicted safe and reliable operation of the assets well beyond the original design life, provided the asset management recommendations made within the study are adhered to.

3:00 PM – Validation of an Ultrasonic Phased Array Tool for Inspection of Weld Overlay Cladding for Subsea Applications

Presenter: Channa Nageswaran, TWI Ltd.

Value to Operators: Weld overlay cladding is one of the options to protect pipelines, including subsea riser systems, from corrosive fluids. Weld overlay cladding develops anisotropic coarse grains during solidification that makes ultrasonic inspection challenging by introducing noise into the signal. Where fatigue critical applications require small flaws, with through-wall heights less than 1mm, to be detected confidently, the increased noise from the weld overlay cladding can

lead to reduced confidence in interpretation of the cladding condition. Hence, a tool that is sensitive to such small critical flaws and brings confidence to the interpretation of the inspection data allows selection of the weld overlay cladding method to be an attractive option. Following this work, the tool is ready for deployment firstly during the pipe fabrication setting in pipe-mills and further investigation for use subsea for in-service inspection is recommended. The validation will support implementation by operators, as well as by automated scanning systems. In particular, the inspection of pipes while being clad can bring significant boosts to productivity by ensuring flaws are caught early, as well as detecting deviations in the welding conditions that give rise to non-uniform deposition. In addition to weld overlay cladding, the tool has been shown to be sensitive to fatigue cracking in mechanically lined pipe, which expands its usefulness to the wider pipeline industry.

Description of the research: The work done in the MATS-1-1 Phase 3 project allowed a tool explored in previous phases to be validated using a statistically relevant number of flaws representing those which were deemed to pose significant threat to the integrity of the pipeline. The validation was done using a procedure developed for implementation by trained operators and the inspection was done blind. The results supplied by the operators were analyzed to establish the probability of detecting three different types of critical flaws. These PoD curves for the tool established its performance limits. The flaws used were a combination of implanted flaws and naturally found flaws, where over 30 flaws (greater than 120 in total) represented each of the three types. The tool is composed of four independent array probes that were configured to run three phased array techniques simultaneously. The data from the three techniques were presented to the operators in order to crosscheck indications so that their interpretation was improved. The parameters of the probes were optimized for the pipeline system selected for the MATS-1-1 program, which in previous phases was focused on materials selection and establishing fatigue performance. However, the tool can be reconfigured for other pipeline systems and limited project specific validations can be used atop the detailed validation done in this project to support its use on these different systems.

How can other operators put this into practice? The tool developed by TWI is not commercially protected and TWI has actively promoted its use in industry for its wider benefit. Other operators are free to recreate this tool and implement it in their construction/inspection projects and TWI can support reconfiguration to different pipeline systems if requested. From the outset, the tool was developed to be operated using typical commercially available portable phased array instruments so that it can be adopted widely. The three techniques can also be readily understood by Level 2 trained phased array technicians/operators, further broadening the ease of its use and adoption. In addition to weld overlay cladding, the principles behind this tool can be applied to a number of damage mechanisms affecting austenitic cladding in pipelines, for example stress corrosion cracking, and for damage in cladding used to protect other critical components such as processing vessels.