DISCLAIMER

This presentation is based on the author’s assessment of information available at the time of writing, and is not intended to be comprehensive, nor is it guaranteed to be free of error. It is assumed that readers will take proper care and due diligence to evaluate offshore and subsea exploration’s risk management options, commensurate with the complexity and possible consequences of such decisions, including securing appropriate formal expert and legal opinions where appropriate. Boston Strategies International (BSI) does not assume any responsibility for omissions, errors, misprinting, or ambiguity contained, and shall not be held liable in any degree for any loss or injury caused by such omissions or errors.
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• Policies, Principles Standards, and Frameworks

• Safeguarding Infrastructure with Physical Barriers and Access Controls

• Pipe Security Technologies

• Selecting Vendors, Assessing Costs and Benefits
Why Pipeline Security Programs?

- **Accidental spills**
  - Montana

- **Accidental fire and explosion**
  - Nigeria
  - China / Sinopec
  - China / PetroChina
  - Mayflower, Arkansas
  - Ghislenghien, Belgium
  - Mexico

- **Malicious attacks**
  - Bicentenario pipeline
  - Caño Limon Coveñas pipeline
  - 259 attacks in 2013, 67 in 2014 H1

- **Oil and gas siphoning activities**
Policies, Principles Standards, and Frameworks
## Laws, Principles, and Standards

### Laws (US)
- Pipeline and Hazardous Materials Safety Administration

### Principles (AOPL)
- Zero Incidents
- Organization-Wide Commitment
- Employ Technology
- A Culture of Safety
- Continuous Improvement
- Communicate with Stakeholders
- Learn from Experience
- Safety Systems for Success Stakeholders
- Reporting

### Standards (API, etc.)
- API 1130 (computational pipeline monitoring)
- API RP 1149, Pipeline Variable Uncertainties and Their Effects on Leak Detectability
- RP 1155, Evaluation Methodology for Software Based Leak Detection Systems
- RP II6l, Guidance Document for Qualification of Liquid Pipeline Personnel, August 2000
- RP III3 Developing a Pipeline Supervisory Control Center
- Canadian Standards Association (CSA) Z662-M99 Oil and Gas Pipeline Systems, Appendix E, "Recommended Practice for Leak Detection"
- ISO pipeline standards
## ISO Pipeline Standards

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## ISO Pipeline Standards

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<td>Pipeline transportation systems Welding of pipelines</td>
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<td>Steel pipe for pipeline transportation systems</td>
<td>Wet thermal insulation coatings for pipelines, flow lines, equipment and subsea structures</td>
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An Integrated Framework

Requirements for safe pipeline operation

- **Materials & Components**
  - material properties
  - pipe specification
  - coating quality

- **Design & Construction**
  - seam weld quality
  - coating inspection
  - pressure testing

- **Operation**
  - surveillance intervals
  - component inspection
  - emergency preparedness

**Laws & Regulations, Technical Rules and Standards**

Heinz Watzka / PTC 2014 / May, 12th 2014
Safeguarding Infrastructure: Physical Barriers and Access Controls

- Barriers
- Gates
- Locks and keys
- Lighting
- Intrusion detection
- Personnel identification and tracking
- Background checks
- Equipment maintenance and construction standards
- Materials, Joining, Construction specifications to minimize corrosion
- Depth of cover
- Pressure Testing
However, Low-Tech Detection Solutions are Often Uneconomical to Scale

**Surveillance challenges:**
- Round-the-clock vigil - Monitoring leakages
- Electronic surveillance - less useful if not incorporated into a complete security system
- Physical ground and/or air patrolling - infrastructure costs are not economically viable
- Long-range radar water and surface-based solution - need for power and network connectivity.

- Armed security guards cannot be everywhere at the same time.
- “Point sensing” detection technologies require many nodes to provide sufficient information.
- Positioning detectors and transmitters correctly can be prone to error.
- Can be disrupted by a single large and often harmless event blinding the system to specific activities that can affect the process.
- Are retrospective, only notify that a damaging event has occurred, allowing an operator to put into place reactive countermeasures to mitigate escalating costs.
Overview of Detection Technologies (From the Outside In)

- UAVs
- Radar/LIDAR
- Intrusion Detection via Image Pattern Recognition
- Infrared Imaging
- Smart Pigging
- Magnetic Flux Leakage
- Ultrasonic Tools
- Geometry Tool
- Distributed Fiber Optic Sensing
- Acoustic Sensors
- Temperature and Strain Sensing
- Electric Field Mapping
- Pipe Coating, Lining and Cathodic Protection
- Cyber-Secure Networks
**Unmanned Aircraft Surveillance, Systems or Vehicles (UAS, or UAV)**

- **Components:**
  - A UAV (Unmanned Aircraft Vehicle)
  - A ground control station to control the UAV operation
  - An interface with the pipeline operator
- **25 kg - 50 kg vehicle**
- Launched using a launching device (like a catapult) or from a field (unimproved runway).
- **200m to 400m above the pipeline.**
- Sensors and computers onboard record the data generated by the cameras, process the data in real time to detect potential threats and disseminate the information as required by the operator.
- Is retrieved at a predetermined location, the data onboard is then downloaded for further exploitation if needed.

Source: ATE Aerosurveillance
• Airborne Light Detection and Ranging (LIDAR) is an aircraft-mounted laser system designed to measure the 3-D coordinates of Earth's surface. It has been proven to be an effective technology for acquiring terrain surface data with high accuracy.

• LIDAR-topographic-mapping systems have considerable promise for producing high-resolution digital elevation models (DEMs). Satellite communications and GPS navigation systems are critical parts of LIDAR mapping systems.

• For Underwater: Scanning Hydrographic Operational Airborne LIDAR System (SHOALS) system provides the capability for high spatial density utilizing state-of-the-art LIDAR technology consisting of a scanning laser transmitter/receiver that produces 200 soundings per second.
Intrusion Detection System Based on Pattern Recognition

• **Components**
  
  • Sensors
  
  • Video Detection Equipment / Closed circuit television (CCTV) security cameras
  
  • Threat Assessment and Alarm Correlation or Management System.
  
  • Data Communication System

![Image Credit: Tata](image1.jpg)

**Figure 1: Change Detection on Satellite Captured Images**
Infrared thermography (IRT), Thermal Imaging, and Thermal Video

• Thermographic cameras detect radiation in the infrared range of the electromagnetic spectrum (roughly 900–14,000 nanometers or 0.9–14 μm) and produce images of that radiation, called thermograms.

• IR film is sensitive to infrared (IR) radiation in the 250°C to 500°C range, while the range of thermography is approximately −50°C to over 2,000°C. So, for an IR film to work thermographically, it must be over 250°C or be reflecting infrared radiation from something that is at least that hot.

• Advantages:
  • Visual picture
  • Nondestructive test method
  • Works in dark areas
In-Line Inspection (ILI): “Smart Pigging”

- Advances in magnetic-based In-Line Inspection (ILI) technology have enabled pipeline operators to reduce corrosion as a cause of pipeline incidents by nearly 80% over the last 15 years.
- Several crack-focused ILI technologies are performing well.
- ILI technology providers and operators are currently harnessing ultrasound, combinations of magnetic and ultrasound, and advanced computer analytic techniques to find and diagnose potential cracks in pipelines.
- Various types of smart pigging are discussed in the following slides:
  - Magnetic Flux Leakage (MFL)
  - Transverse MFL / TFI
  - Ultrasonic Tools
  - Geometric Tools

Source: aopl.org
Magnetic Flux Leakage (MFL)

- Electronic tool that identifies and measures metal loss (corrosion, gouges, etc.) through the use of a temporarily applied magnetic field. As it passes through the pipe this tool induces a magnetic flux into the pipe wall between the north and south magnetic poles of onboard magnets.
- A homogeneous steel wall – one without defects – creates a homogeneous distribution of magnetic flux. Anomalies (i.e., metal loss (or gain) associated with the steel wall) result in a change in distribution of the magnetic flux, which, in a magnetically saturated pipe wall, leaks out of the pipe wall.
- Sensors onboard the tool detect and measure the amount and distribution of the flux leakage. The flux leakage signals are processed, and resulting data is stored onboard the MFL tool for later analysis and reporting.

Source: primis.phmsa.dot.gov
Transverse Flux Inspection (TFI)

- Identifies and measures metal loss through the use of a temporarily applied magnetic field that is oriented circumferentially, wrapping completely around the circumference of the pipe.
- It uses the same principal as other MFL tools except that the orientation of the magnetic field is different (turned 90 degrees).
- The TFI tool is used to determine the location and extent of longitudinally-oriented corrosion. This makes TFI useful for detecting seam-related corrosion.
- Cracks and other defects can be detected also, though not with the same level of reliability.
- A TFI tool may be able to detect axial pipe wall defects – such as cracks, lack of fusion in the longitudinal weld seam, and stress corrosion cracking – that are not detectable with conventional MFL and ultrasonic tools.

Source: primis.phmsa.dot.gov
Ultrasonic Tools

- Compression Wave Ultrasonic Testing (UT) : measure pipe wall thickness and metal loss. These tools are equipped with transducers that emit ultrasonic signals perpendicular to the surface of the pipe. An echo is received from both the internal and external surfaces of the pipe and, by timing these return signals and comparing them to the speed of ultrasound in pipe steel, the wall thickness can be determined. This is especially important for crude oil lines.

- Shear Wave Ultrasonic Testing (also known as Circumferential Ultrasonic Testing, or CUT) is the nondestructive examination technique that most reliably detects longitudinal cracks, longitudinal weld defects, and cracklike defects (such as stress corrosion cracking). It uses shear waves generated in the pipe wall by the angular transmission of UT pulses through a liquid coupling medium (oil, water, etc).

Source : primis.phmsa.dot.gov
Geometry Tools

- Geometry tools use mechanical arms or electromechanical means to measure the bore of pipe. In doing so, it identifies dents, deformations, and other shape changes.
- It can also sense changes in girth welds and wall thickness. In some cases, these tools can also detect bends in pipelines.
- The remediation criteria depend on both the depth and orientation of dents, so geometry tools that are used to detect deformation anomalies such as dents, should provide both the orientation, location and depth measurement of each dent.
- This tool can be used for hazardous liquids and natural gas pipelines.

Source: primis.phmsa.dot.gov
Distributed Fibre Optic Sensing

- Distributed optical fibre sensors offer the capability of measuring at thousands of points simultaneously, using a simple, unmodified optical fibre as the sensing elements.
- Resistive strain gages are the most common sensor type and are composed of a zigzag pattern of copper foil that is calibrated to produce voltage changes proportional to the pattern’s geometric expansion due to being glued onto the underlying material.
- Once the gauges have been attached and the lead wires have been bundled and routed, all of the signals must be connected to a centralized data collection system with an array of channels. With individual calibration constants, the sensing channel for each gauge must be adjusted in order to accurately measure strain, resulting in bundles of electrical wires that are running along the structure, occupying space and requiring regular maintenance to ensure that they really work.
- There are 2 main types of DFOS systems currently in use in Oil & Gas for Pipeline Safety-
  - Distributed Acoustic Sensing (DAS)
  - Distributed Temperature & Strain Sensing (DTSS)

Source: ctemps.org
Acoustic Sensor for Leakage detection

Figure 8: UTCD/UTWM Ultrasonic Tool

Figure 11: Weatherford’s latest generation of Ultrasonic sensors

Source: Weatherford
Distributed Temperature and Strain Sensing (DTSS)

• DTSS are sophisticated sensor systems using Brillouin scattering in optical fibers to measure changes in both temperature and strain along the length of an optical fibre.

• By wrapping or embedding a fibre inside a structure, such as an oil pipeline or dam, one can detect when the structure is being strained or heated/cooled, and correct the problem before failure occurs. The sensing technology gives both strain and temperature readings along the length of the fibre, with spatial resolution as short as 10 cm.

• Depending on the configuration selected, measurements can be made over the entire length of fibre, up to 100 km in length. One can use such a setup to monitor a very long length device, like a pipeline or highway, or lay the fibre to form a 2D or 3D grid in a structure, like a dam wall or submarine hull.

• Measurements can be made up to the entire length of fibre (Typically 100km)

Source: ozoptics.com
Electric Field Mapping (EFM) for Corrosion Monitoring

- The system uses an array of electrodes to measure localized differential voltages and map the electrical field generated by a controlled current. Changes in resistance occur from variations in both metal thickness and temperature.
- Temperature variations normally occur with ambient and process condition changes. The PinPoint Electrical Field Mapping (EFM) system measures these temperature variations and compensates the resistance values accordingly.
- The system utilizes bi-directional, pulsed DC excitation current to provide a dual scan of the corroded area through up to 512 differential voltage sensors to dimensionally define isolated pit defects.
Pipe Coating, Lining and Cathodic Protection Methods

- Bituminous wrap
- Cement coating for impermeability, protection against attack
- High Performance Polyurea Spray Coatings
- Epoxies
- Polyethylene
- FBE
- Electro Magnetic Acoustic Transducer (EMAT)
- “Laproscopic” pipe repair
- Installation of sensors during repair
- Optimizing viscosity and chemical properties
- Maintenance of cathodic protection

Source: Adria Wien Pipeline GmbH (subsidiary of OMV)
Cyber-Secure Networks (Integrated/Advanced Telecommunication Systems)

- **Cyber-security protection**
  - Secured communications
  - Distributed Denial of Service (DDoS) protection
  - Firewall
  - Antivirus/Malware

- **Integrated life-safety systems**
  - Intrusion Detection System (IDS)/ Intrusion Prevention System (IPS)
  - Security Information and Event Management (SIEM)

- **Interference minimization**
  - Impact of high voltage overhead line on pipeline security

- **Data recovery and backup**
  - Data Loss Prevention (DLP)
  - Recovery and restoration solutions
Selecting Vendors, Assessing Costs and Benefits
Pipeline Security Technology Selection and Economic Cost-Benefit Evaluation Process

Benefits Assessment

Cost Management

Strategic, Fact-Driven Vendor Selection and Negotiating Process

- Independent Cost Estimating
  - Benchmark Project Economics
  - Capital Project Cost Estimates
- Value Chain Engineering
  - Determine Ways to Achieve Target Economics
  - Supply Chain Strategy (for Buyers)
- Tender Design & Management
  - Ensure Capacity Availability, Price Stability
  - Supplier Prequalification Technology Selection
- Supply Contract Negotiation
  - Make price-risk tradeoffs
  - Ensure Total Cost basis
  - Negotiation preparation Finalization of Terms and conditions
- Contract Administration
  - Control in project execution
  - Objective claim drafting & rebuttal
  - Claims Drafting
  - Rebuttals and Defenses
KPIs: Number of Incidents
Reduction in incidents 50% from 1999-2013 (AOPL, 2013)
KPIs: Root Causes

78% Reduction in Incidents Caused by Third Party Construction

Causes of Top 10 Liquids Pipeline Releases in 2013

- Natural Force Damage (Lightning, Landslide) 32%
- Other Outside Force Damage (3rd Party Barge Strike) 24%
- Material, Seam or Weld Failure 24%
- Corrosion 8%
- Operator or Contractor Damage 4%
- 3rd Party Excavation Damage 4%
- Equipment Failure 4%

Source: PHMSA Pipeline Incidents Database
KPIs: Magnitude of Incidents
More Self-Contained, and Smaller, Incidents Over Time

Most Liquids Pipeline Incidents Are Inside Operator Facilities, with Lower Impact on the Public or the Environment

Source: Comparison of PPTS Pipeline Right of Way Incidents and PHMSA Total Pipeline Incidents

Most Liquids Pipeline Incidents Are Very Small

2013 PHMSA Reported Incidents by Size Smallest to Largest
Contact Information

David Jacoby
President
BOSTON STRATEGIES INTERNATIONAL
E-mail: djacoby@bostonstrategies.com, djacoby@ogpnetwork.com
USA Mobile: +1 617 593 2620
Skype: david.jacoby1
LinkedIn: http://www.linkedin.com/pub/david-jacoby/8/b91/8b9