REX2024
PRCI Research Exchange

Managing Scaleup Challenges: Pipeline Integrity Monitoring Innovations for Long Distance Deployments

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PRCI LEADING PIPELINE RESEARCH

Pipeline Research Council International

Overview

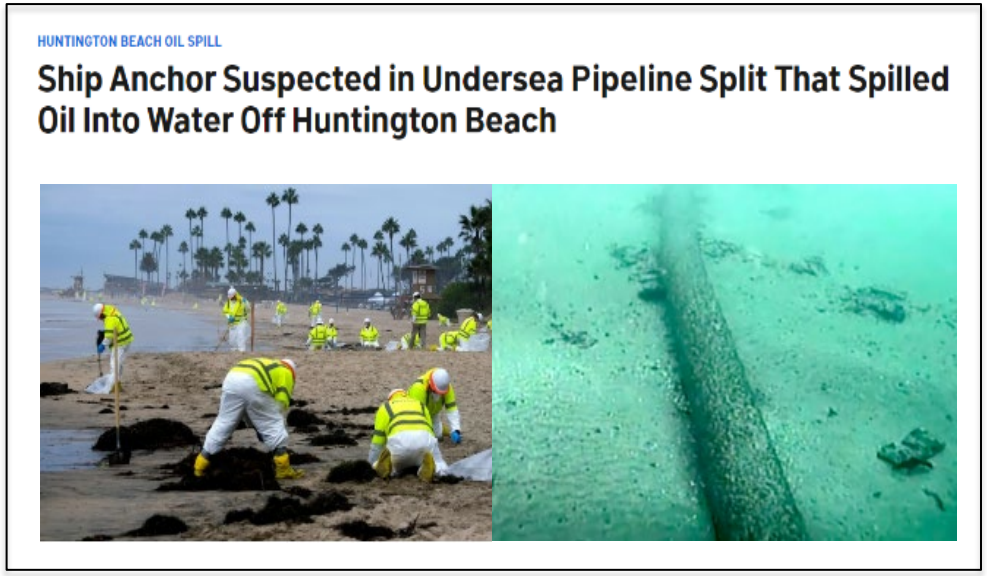
- Hifi Company Background
- Distributed Fiber Optic Sensing (DFOS)
- Long Distance Architecture for Pipeline Monitoring
- Deployment Challenges
- Deployment Solutions
- Post-Deployment Challenges
- Post-Deployment Solutions
- Conclusion

Hifi Company Background

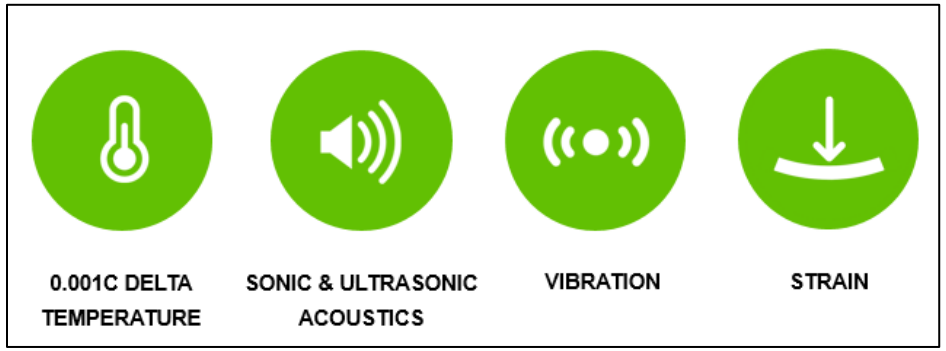
- Founded 2007, Calgary, Alberta, Canada
- Technology service provider focused on turnkey distributed fiber optic sensing systems including fiber/sensors, hardware and machine learning software
- Next generation high fidelity distributed sensing (HDS™) optical technology
- Expert team of engineers developing custom machine learning/AI applications
- In-house technology development powered by 100+ patents
- Members of FOSA & ECC: Fiber Optic Sensing Association (Connect and Protect); Energy Connections Canada
- Strategic investors – core pipeline integrity focus: cenovus energy; Enbridge; bdc
- HDS deployed or pending deployment on > 10 million pipeline feet
- Recent Awards & Recognition:
  - 2023 (and 2022) FOSA Innovation of the Year
  - 2023 (and 2019) Energy Connections Canada / CEPA Innovator of the Year
  - 2023 (and 2022) SDTC Canada's Sustainability Changemakers
  - 2023 (and 2021) Deloitte Tech Fast 500 & Clean Tech Awards

Distributed Fiber Optic Sensing (DFOS)

- **Pipeline leaks extremely damaging to the environment and costly to clean up**
- **100% coverage requires continuity of monitoring in both time and space**

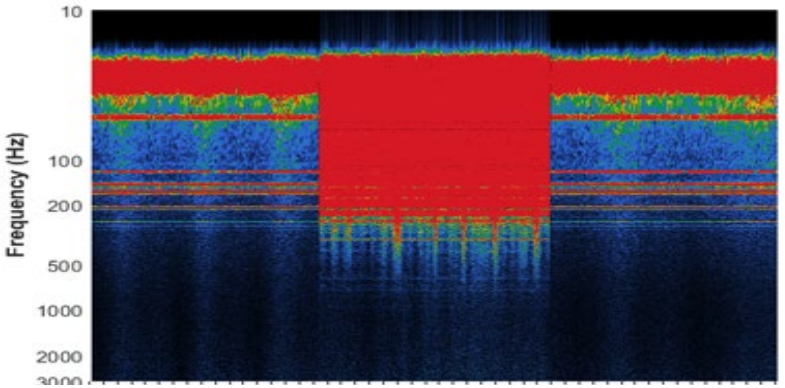


- **Every inch of the DFOS fiber is sensitive and measuring:**
  - Acoustics
  - Vibration
  - Strain
  - Differential temperature



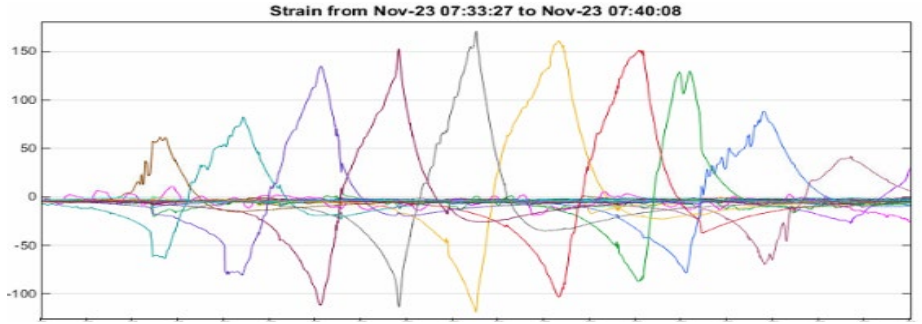
DFOS Value-Added Applications

- **Value-added applications include:**
  - Preventative leak detection
  - Intrusion detection
  - Pig tracking
  - Strain monitoring
  - Flow tracking

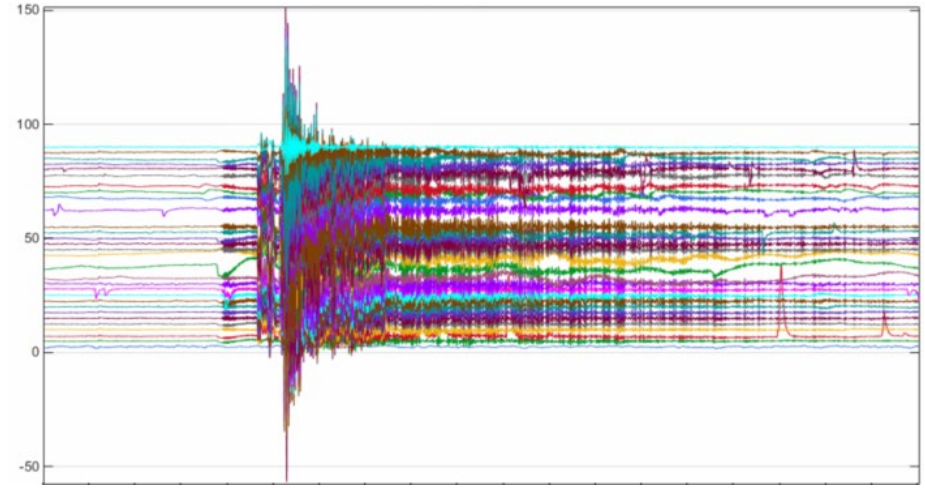


Leak signature

Intrusion signature



Pigging signature



Seismic event signature

Long Distance Pipeline Fiber Deployment

Deployment in multi-microduct conduit (HDPE) or stainless-steel capillary tubing

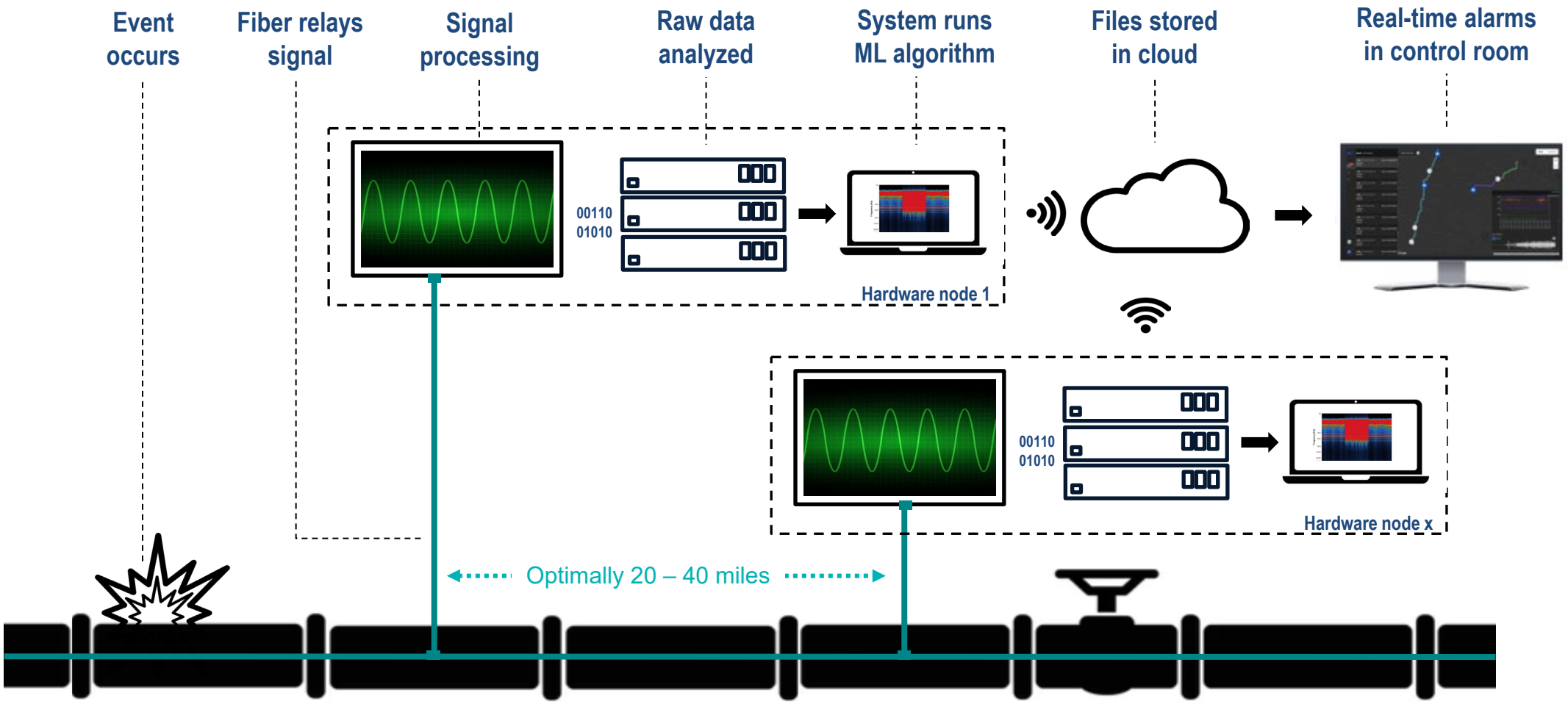
On-Pipe
(Greenfield)

Near-Pipe
(Greenfield)

Near-Pipe
(Brownfield / Retrofit)

In-Pipe
(Brownfield / High Consequence Areas)

From Pipe to Control Room



Fiber Optic Sensor
Senses acoustics, temperature & vibration/strain

System Hardware
Computational horsepower for local processing of Big Data

Software & Algorithms
ML-based algorithms for characterization of events & cloud-based user interface

1200 km Pipeline Deployment Opportunity

- Monitor every inch of the pipe
- Comply with regulatory requirements for leak and intrusion detection
- Prevent damage to the pipe via the early identification of integrity concerns such as ground disturbance and slope stability
- Enable other value-added applications (pig tracking, flow tracking, thermal anomaly detection, ...)

1200 km Pipeline Deployment Challenges

- **Conduit deployment:**
  - Open cut sections
  - Mountainous terrain
  - River crossings
  - Brown-field retrofitting
- **Fiber injection**
- **Splice handhole and system hardware location selection**
- **Optimal design of optical architecture to maximize data quality**
- **Continuous adaptation of the optical architecture to field deployment realities**

1200 km Pipeline Deployment Challenges

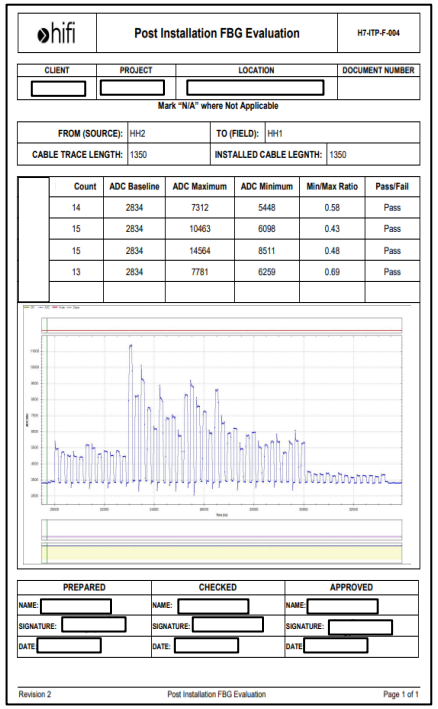
Conduit crushing

Conduit kinking

Slack allowance required

1200 km Pipeline Deployment Solutions

- **Various methods of conduit deployment utilized:**
  - Horizontal Directional Drills (HDD) with redundant conduits
  - Micro-tunneling
  - Auger bore
  - Direct pipe
- **Rigorous post-injection evaluation to ensure fiber is not damaged or over-strained**
- **Long-distance architecture optimization software program developed to identify optimal hardware node and handhole locations based on:**
  - Optical loss budget
  - Minimization of hardware requirements
  - Location accessibility (i.e., near road crossings)


hifi | Post Installation FBG Evaluation | H7-ITP-F-004

CLIENT	PROJECT	LOCATION	DOCUMENT NUMBER

Mark "N/A" where Not Applicable

FROM (SOURCE):	HH2	TO (FIELD):	HH1
CABLE TRACE LENGTH:	1350	INSTALLED CABLE LEGNTH:	1350

Count	ADC Baseline	ADC Maximum	ADC Minimum	Min/Max Ratio	Pass/Fail
14	2834	7312	5448	0.58	Pass
15	2834	10463	6098	0.43	Pass
15	2834	14564	8511	0.48	Pass
13	2834	7781	6259	0.69	Pass

PREPARED	CHECKED	APPROVED
NAME:	NAME:	NAME:
SIGNATURE:	SIGNATURE:	SIGNATURE:
DATE:	DATE:	DATE:

Revision 2 | Post Installation FBG Evaluation | Page 1 of 1

Post-injection fiber evaluation report

Handhole placement

Retrofitting existing section

HDD redundancy

Conduit deployed On-pipe

Fiber injection

1200 km Pipeline Deployment Solutions

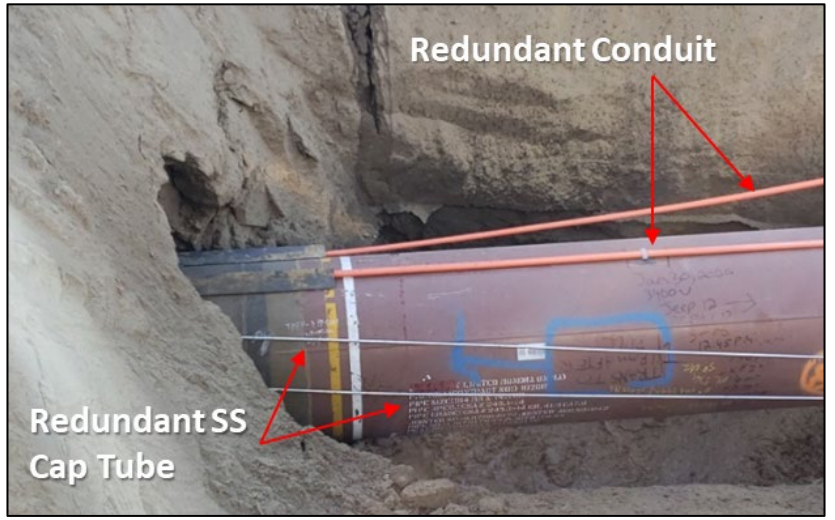
Conduit installation in concrete casing

Conduit installation with weight bags

High redundancy prior to tunnel fill

HORIZONTAL DRILL (HDD & HDB) CONSIDERATIONS

- **Considerable learnings from dozens of successful Horizontal Directional Drills (HDD) and Bores (HDB), including use of:**
  - Armored connections on pull head
  - Redundant conduit and SS capillary tubing to ensure survivability of fiber host given ‘one & done’ nature of HDDs
  - Proximity remains a challenge for trenchless crossings; best practice is to bore wide of existing pipe & reacquire proximity after crossing



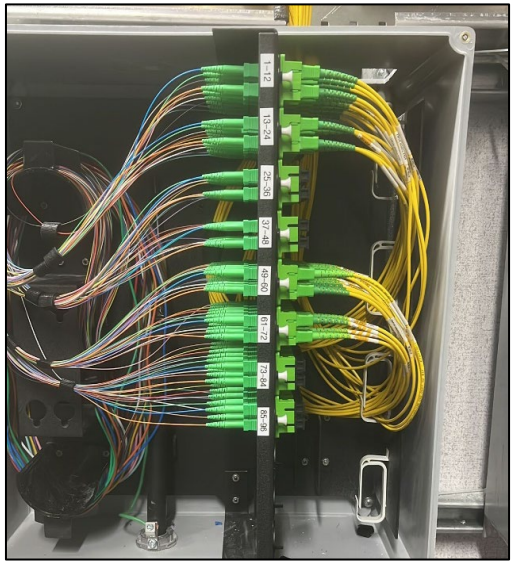
Near-Pipe Retrofitting



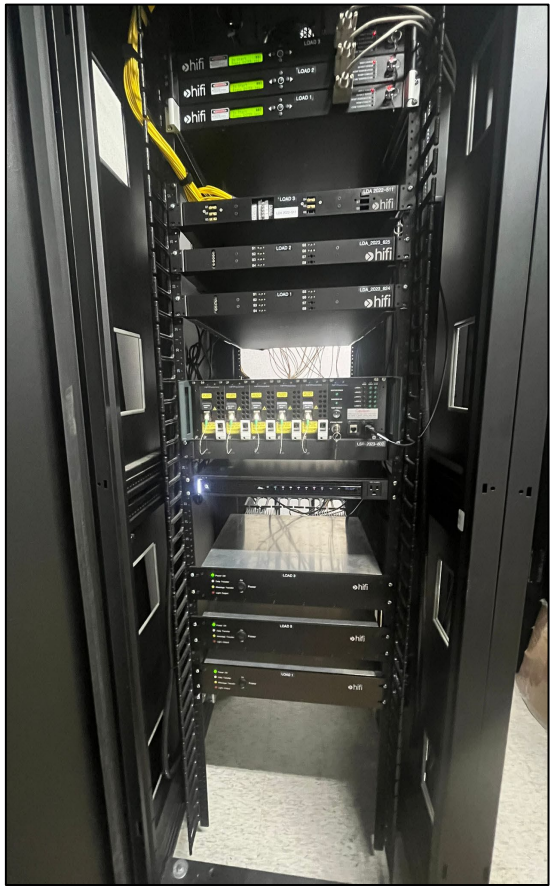


1200 km Pipeline Post-Deployment Challenges

- Managing optoelectronic hardware deployed at numerous locations
- Real-time analysis & storage of hundreds of terabytes of data acquired daily
- Computationally intensive field-deployed Machine Learning (ML) models.
- Changing pipeline operating conditions



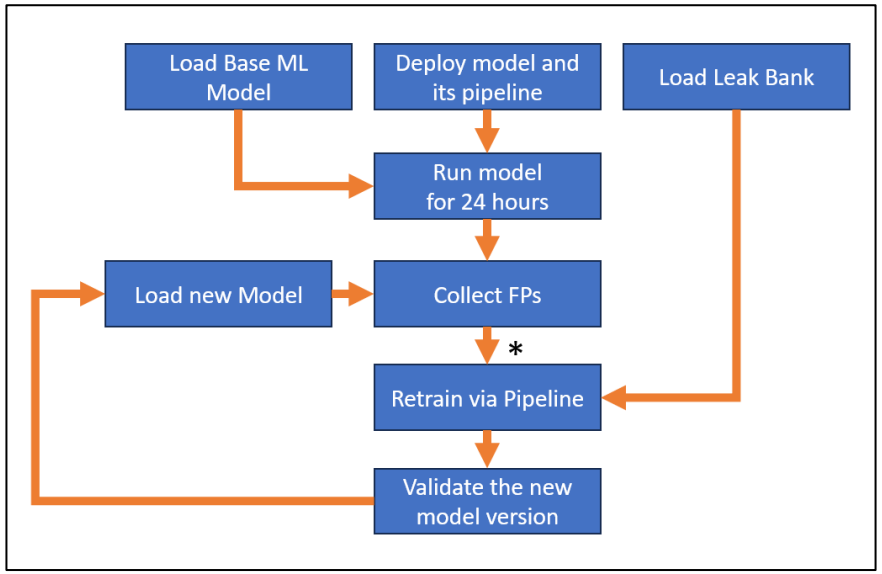
Fiber optic interconnects



Optoelectronic equipment at a hardware node

1200 km Pipeline Post-Deployment Solutions

- **Fleet management system implemented to automate:**
  - Remote firmware upgrade of optoelectronic equipment
  - Remote software push operations
  - System recovery from error states
  - Diagnostic monitoring of the equipment's operating environment (e.g. room over-temperature conditions)
  - Central dashboard for event and diagnostic monitoring
- **ML Ops framework implemented to automate:**
  - ML observability data collection and analysis
  - ML model retraining with new data
  - Monitoring and capping computing resource utilization of ML models during training and inference
- **Dynamic baselining to automate:**
  - Ambient baseline data collection under various operating conditions



ML Operations workflow

1200 km Pipeline – Accelerated Commissioning

- **As per the Canadian Energy Regulator (CER) and Canadian Standards Association (CSA) regulation Z662 Annex E requirements, the external leak detection system must be commissioned during pipeline operations. Therefore, it's imperative to operationalize the DFOS solution as quickly as possible.**

- **Accelerated system commissioning enabled by**
  - Fiber optic system tuning automation
  - Site Acceptance Testing (SAT) automation
  - Utilizing a combination of:
    - Physical leak simulation at a few field sites, and
    - Digital deep fake leak simulations at all field sites

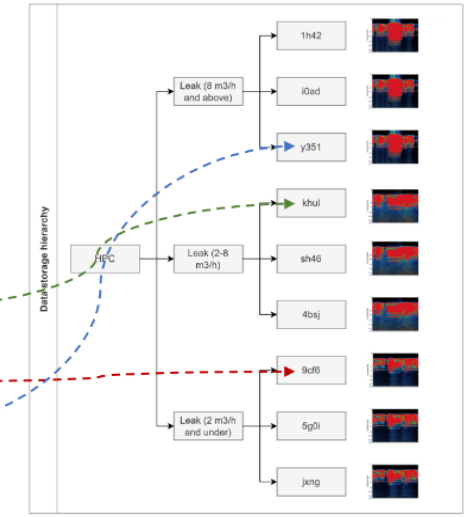
Future Operational Planning

- **To assure reliable operations, monitoring systems have been equipped with:**
  - Automated noise classification & correction
  - Self-tuning features
- **Each pipeline segment will be subject to annual physical or digital leak simulations**

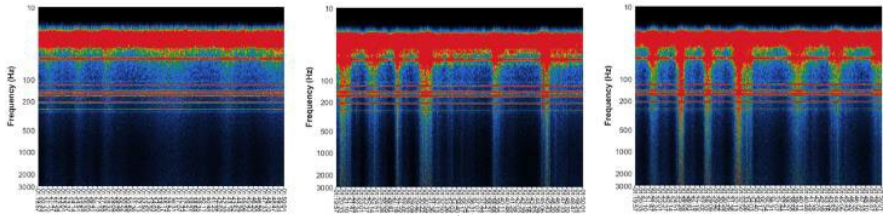
Digital Leak Simulation

Leak catalog

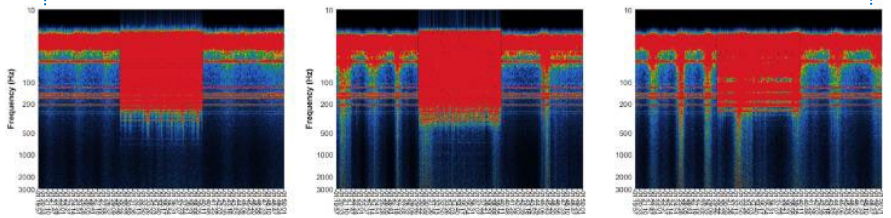
Leak ID	Leak duration in second	Leak location in channel	Leak intensity in psi	Leak storage
i0ad	30	222	600	
khul	60	222	400	
jxng	30	222	100	
sh46	600	100	300	
gcf6	300	320	50	
5g0i	300	50	150	
y351	60	222	800	
1h42	120	240	700	
4bsj	600	150	250	



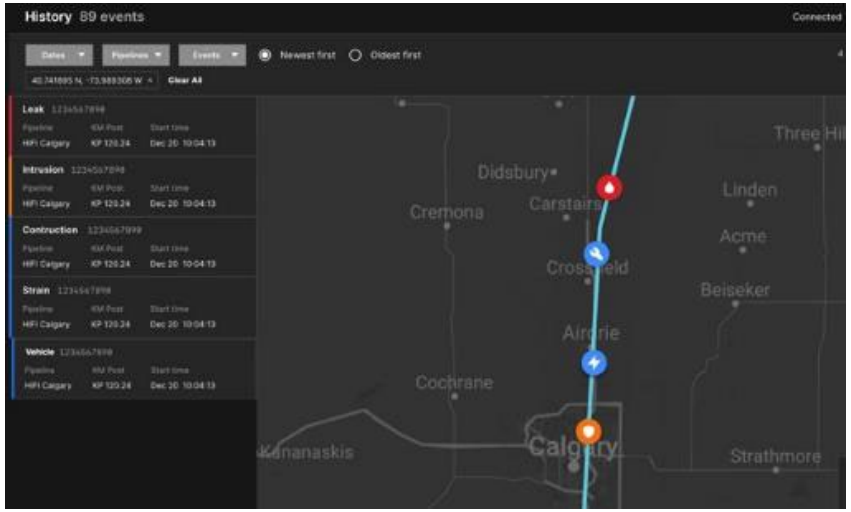
Real time data

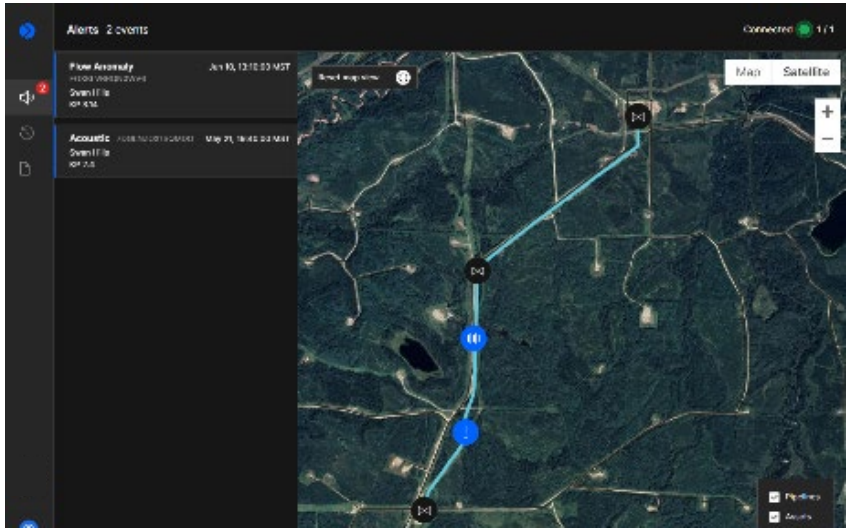


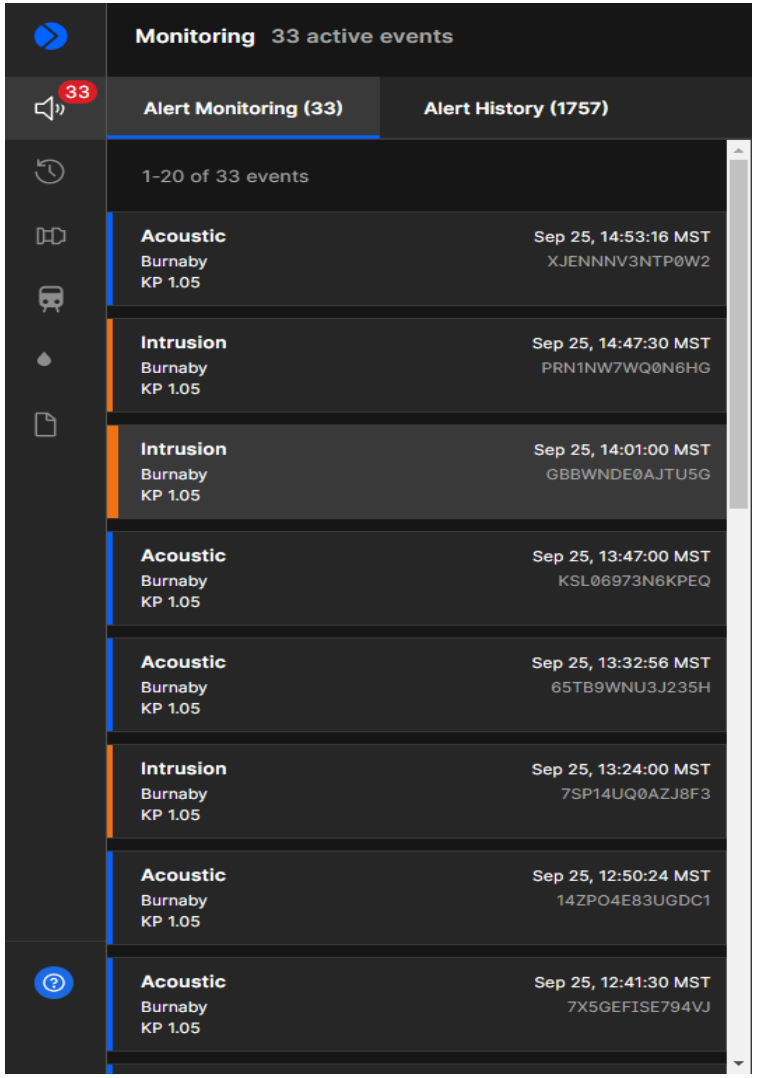
Fake leak blended with real time data

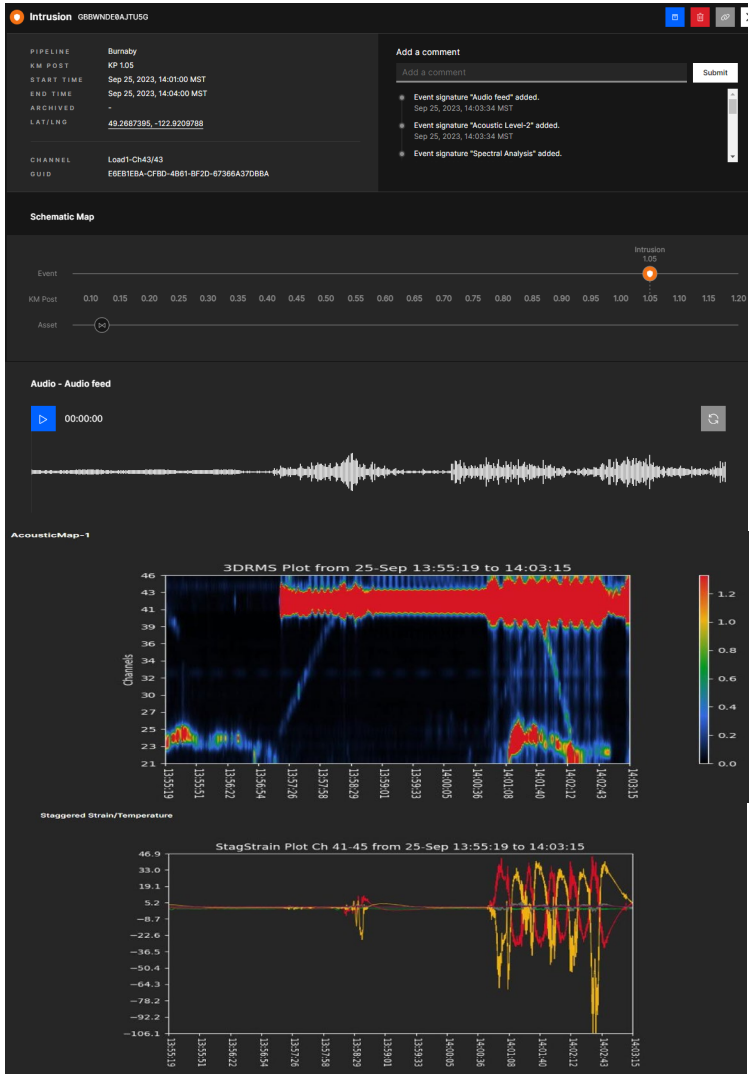


Adaptive Control Room Software User Interface









Conclusion

- High fidelity DFOS and advanced AI/ML algorithms have enabled many value added applications such as leak detection, intrusion detection, pig tracking, and strain monitoring.
- Deployment along very long distances presents a number of major challenges, including fiber and conduit installation issues, hardware fleet management, and the handling of substantial data volumes.
- Automation and digitization are key to enabling such major scaleup operations and assuring their continued post-commissioning success

thank you

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