Managing Scaleup Challenges:
Fiber Optic Deployment & Integrity Monitoring Innovations for Long-Distance Pipelines

Steven Koles - Hifi

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Hifi Company Background

- Founded 2007

- 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:

- Strategic investors – core pipeline integrity focus:

- HDS deployed or pending deployment on > 10 million pipeline feet

- Recent Awards & Recognition:
  - 2023 (and 2019) Energy Connections Canada / CEPA Innovator of the Year
  - 2022 FOSA Project of the Year – TransMountain Expansion Pipeline

Distributed Fiber Optic Sensing (DFOS)

- Pipeline leaks extremely damaging & costly

- Integrity management with 100% coverage requires continuity of monitoring across both <u>time & space</u>

HUNTINGTON BEACH OIL SPILL

Ship Anchor Suspected in Undersea Pipeline Split That Spilled Oil Into Water Off Huntington Beach
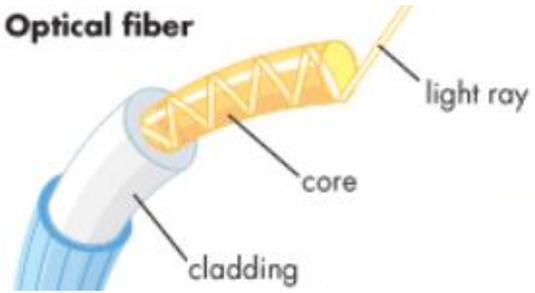
Distributed Fiber Optic Sensing (DFOS)

Every inch is sensitive and measuring:

Optical fiber — light ray, core, cladding

- Acoustics
- Vibration
- Strain
- Temperature

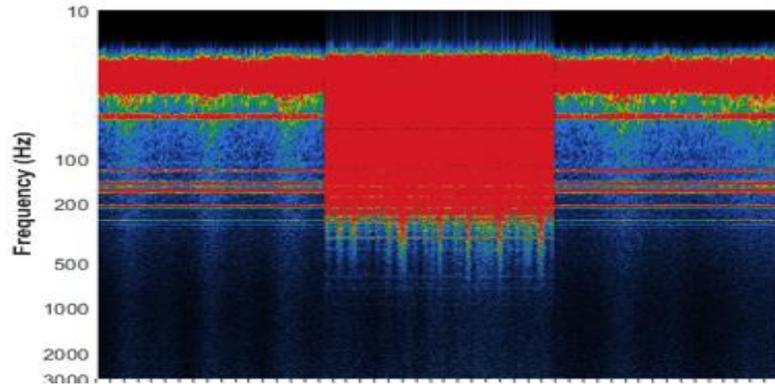

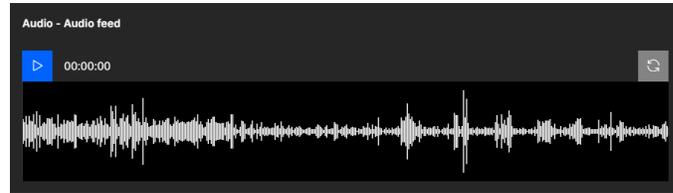| 0.001C DELTA TEMPERATURE | SONIC & ULTRASONIC ACOUSTICS | VIBRATION | STRAIN |

DFOS Value-Added Applications
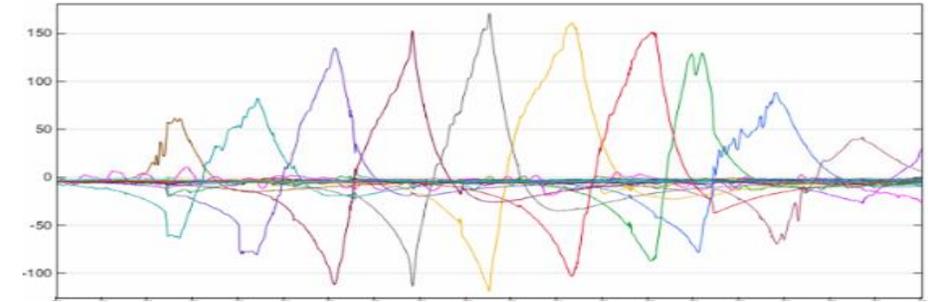
Value-added / machine learning applications include:

- Preventative leak detection
- Strain / geotechnical monitoring
- Intrusion detection
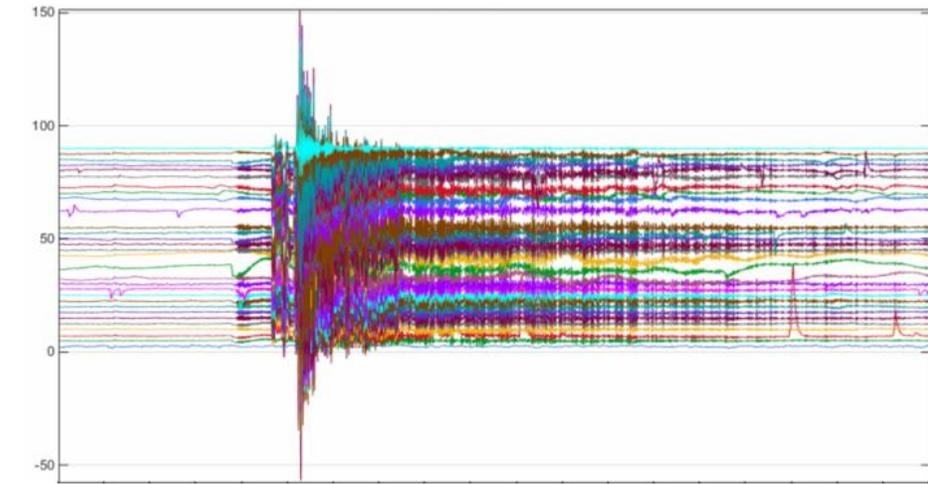- Pig tracking
- Flow tracking

Pigging Signature

Leak Signature

Intrusion Signature

Seismic Event Signature

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Long-Distance Pipeline Fiber Deployment

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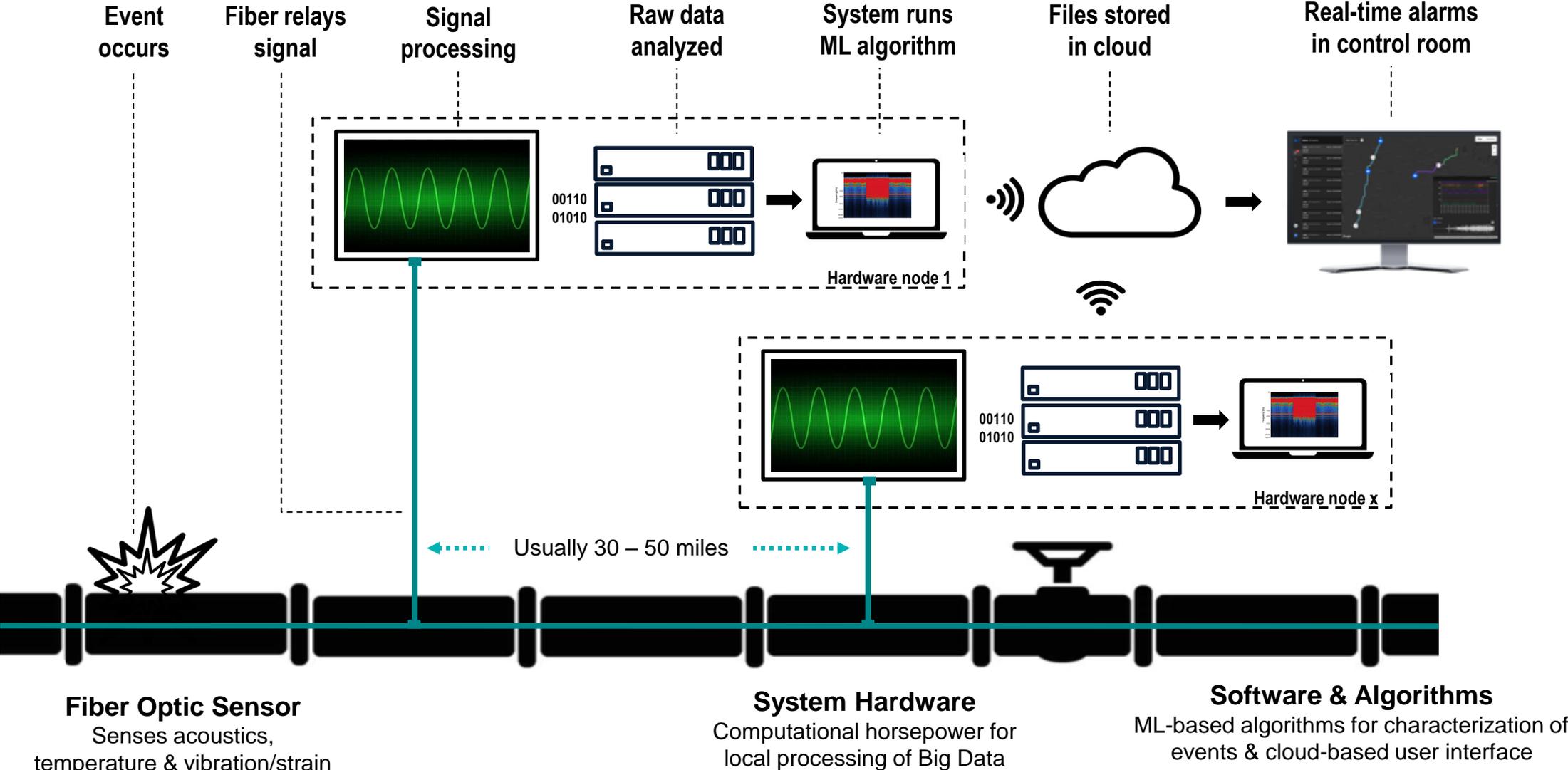

On-Pipe
(Greenfield)

Near-Pipe
(Greenfield)

Near-Pipe
(Brownfield / Retrofit)

In-Pipe
(Brownfield / High
Consequence Areas)

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From Pipeline to Control Room

Event occurs

Fiber relays signal

Signal processing

Raw data analyzed

System runs ML algorithm

Files stored in cloud

Real-time alarms in control room

00110 01010

Hardware node 1

00110 01010

Hardware node x

Usually 30 – 50 miles

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

800 Mile Pipeline Deployment Opportunity

- TransMountain Expansion Pipeline

- Monitor every inch of the pipe

- Regulatory and standards compliance requirements

- Preventative identification of integrity concerns

- Enable other value-added machine learning applications including hybrid fiber optic networking

800 Mile Pipeline Deployment Challenges

- Conduit deployment and retrofitting through various construction techniques and difficult environments

- Long distance fiber injection

- Splice handhole and system hardware location selection

- Optimal design and continuous evolution of optical architecture

Previous Deployment Lessons Learned

Conduit Crushing

Conduit Kinking

Slack Allowance Requirements

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800 Mile Pipeline Deployment Solutions

- More robust conduit
- Various methods of conduit deployment to support trench & trenchless construction (HDD's) as well as retrofitting existing pipe
- Handhole vault design & placement
- Fiber post-injection evaluation
- Long-distance architecture optimization software program

Handhole Placement

Retrofit Existing Sections

On-Pipe Conduit Deployment

HDD Redundancy

Fiber Injection

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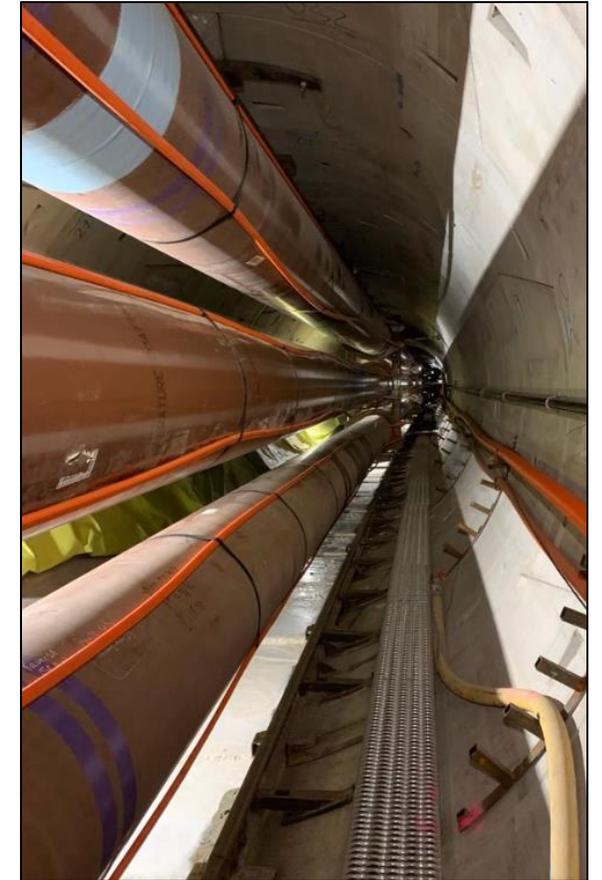CELEBRATING 30 YEARS 1995 - 2025

800 Mile Pipeline Deployment Solutions

Conduit installation in concrete casing

Conduit installation with weight bags for buoyancy

High redundancy prior to tunnel fill

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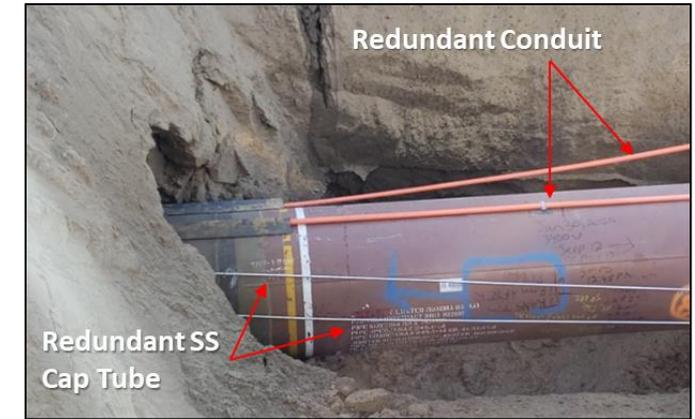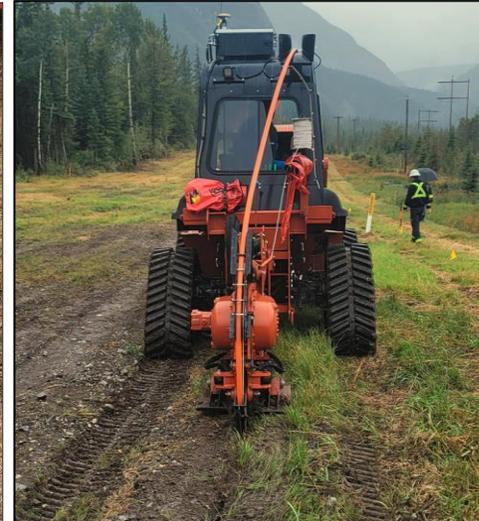Construction. Rehabilitation. Asset Management.
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Horizontal Drill (HDD & HDB) Considerations

Learnings:
- Armored connections on pull head
- Redundant conduit & SS capillary tubing

Redundant Conduit

Redundant SS Cap Tube

CC-002

CC-001

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Horizontal Drill (HDD & HDB) Considerations

- Conduits should not cross paths
- Use of a spreader bar helps guide conduits into borehole

Spreader Bar

Do not cross the lines!

Redundant Conduits

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Near-Pipe Retrofitting

- Specialized vibratory plow and excavation machines utilized
- Target accurate placement < 3 feet away from the pipe at the 3 o'clock position
- Over 150 miles successfully completed without any safety issues

800 Mile Pipeline Post-Deployment Challenges

- Optoelectronic & CPU hardware locations (power)

- Real-time analysis & storage of 100's of terabytes of data

- Computationally intensive field-deployed Machine Learning (ML) models

- Changing pipeline operating conditions

Fiber optic interconnects

Optoelectronic equipment at a Indoor ROW location (pump station)
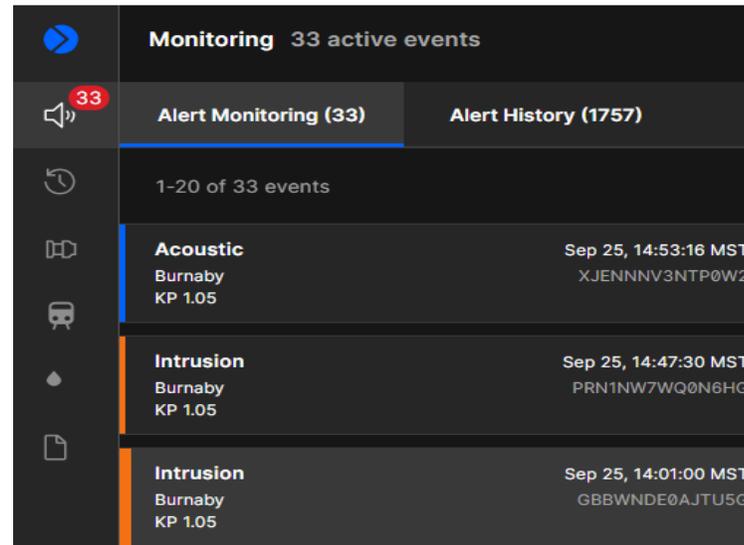
800 Mile Pipeline Post-Deployment Solutions

Fleet management system automates:

- Remote firmware upgrade of optical / IT equipment

- Remote software updates

- System error recovery

- Diagnostic monitoring of equipment's operating environment

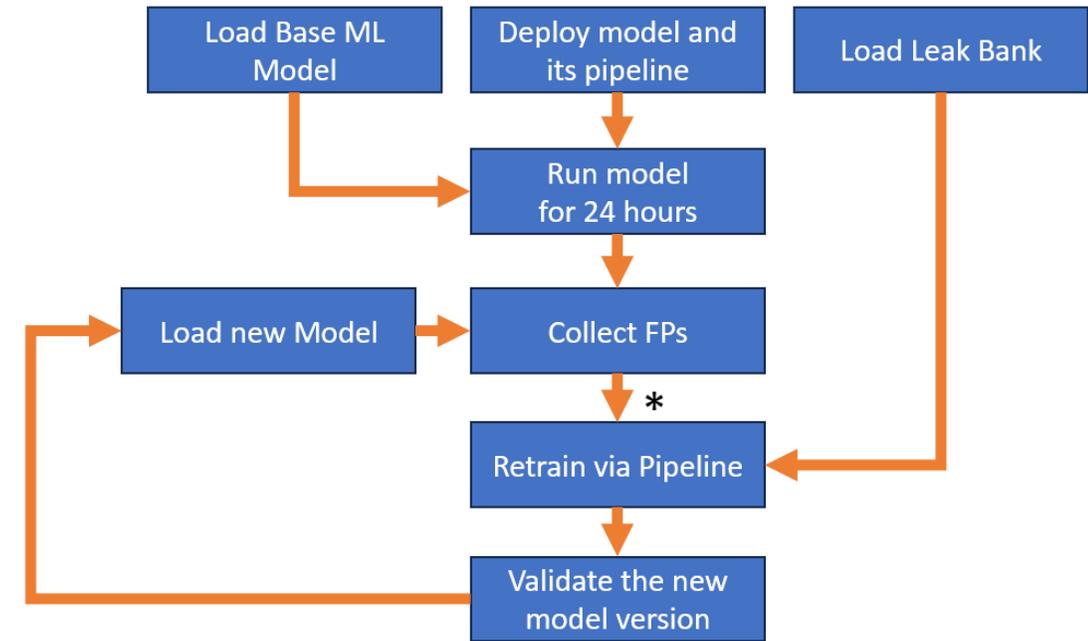- Adaptive central map based dashboard

800 Mile Pipeline Post-Deployment Solutions

ML Ops framework automates:

- ML data collection & analysis

- ML model retraining

- Monitoring and capping computing resource utilization of ML models

Dynamic baselining & SAT testing automates:

Ambient baseline data collection under various operating conditions
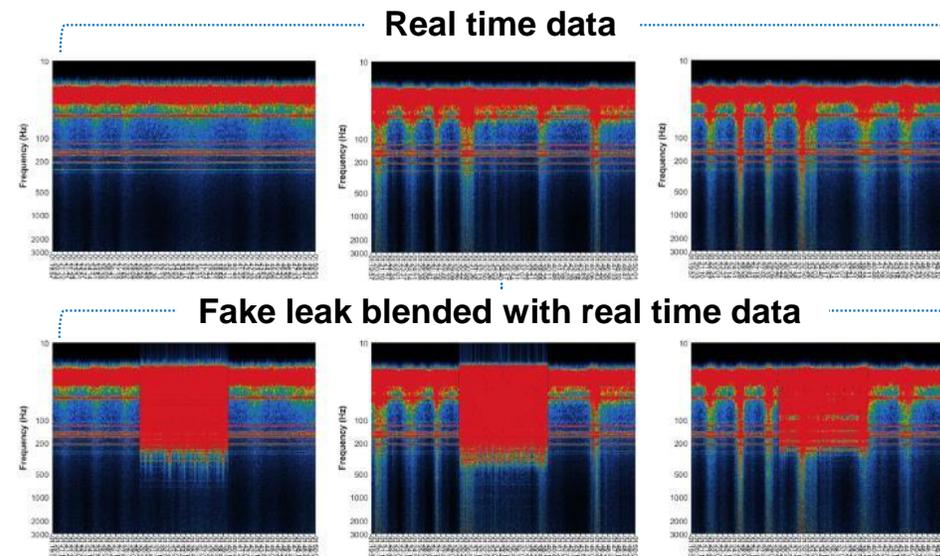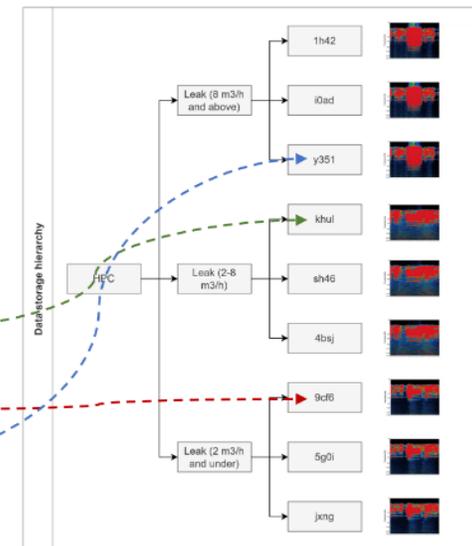

Machine Learning Operations Workflow

Future Operational Planning

- Equip monitoring systems with automated noise classification & correction and self-tuning features

- Each pipeline segment subject to annual physical and/or ML-based "Deep Fake" digital leak simulations

Digital Leak Simulation

Real time data

Fake leak blended with real time data

Conclusions

- High-fidelity DFOS and advanced Machine Learning have enabled many preventative & value-added pipeline monitoring applications.

- Deployment over very long distances presents major challenges: fiber and conduit installation issues, hardware fleet management, and handling substantial data volumes.

- Innovation deployment techniques, automation & Machine Learning are key to enabling such major scaleup operations and assuring their post-commissioning success.

- Thank You & Questions – skoles@hifieng.com