# Composite Systems for Hydrogen Transmission and Localized Storage

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BrainDrip™
Patently True Innovations

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# Transmission and Energy Storage

**BrainDrip's Innervated Tubular Composite (ITC) was created out of a need for innovation within the energy storage market**

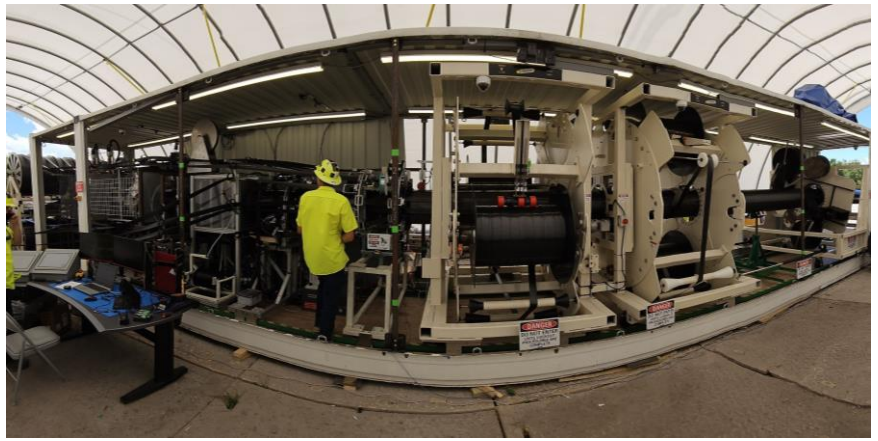
- A purpose-built carbon fiber reinforced, polymer vessel
- Stores and distributes gaseous hydrogen up to 7,500 psig
- Novel onsite manufacturing
  - Field Deployable, Advanced QA/QC
- Project specific customization
  - 6" to 36" diameter
  - 50 feet to 20+ miles

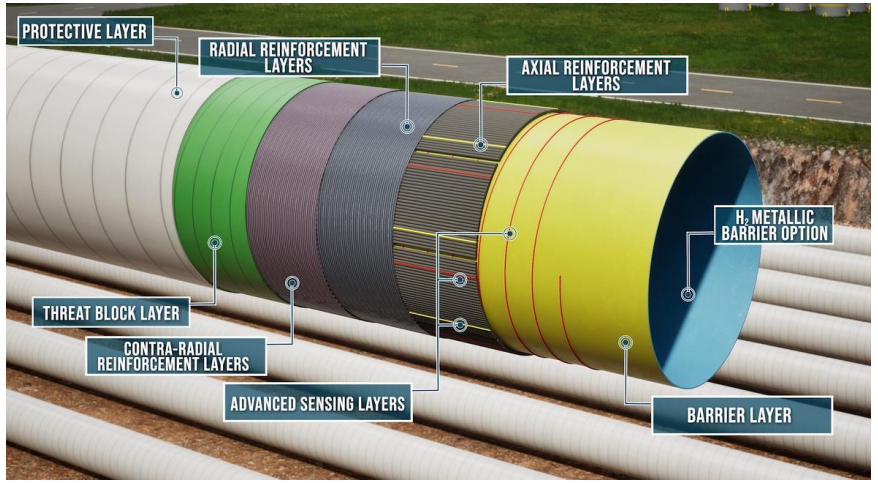
Mobile Manufacturing Plant
Being Deployed to Demo Site

# Our Solutions

## Energy Transmission SG Liner

- Distribution of high-pressure H2, natural gas, CO2, and most fluids
- Purpose built for the pipeline transmission sector
- Pull through technology allows for multi-mile install with only two access points






## Energy Storage GigaVault

- Single Site Installation
- Conforms to Energy Storage Requirements
- Multiple Design Layout Options
- Targeted for Large Scale Storage

  (I.E., 1,000+ kg H2)

# Innervated Tubular Composite

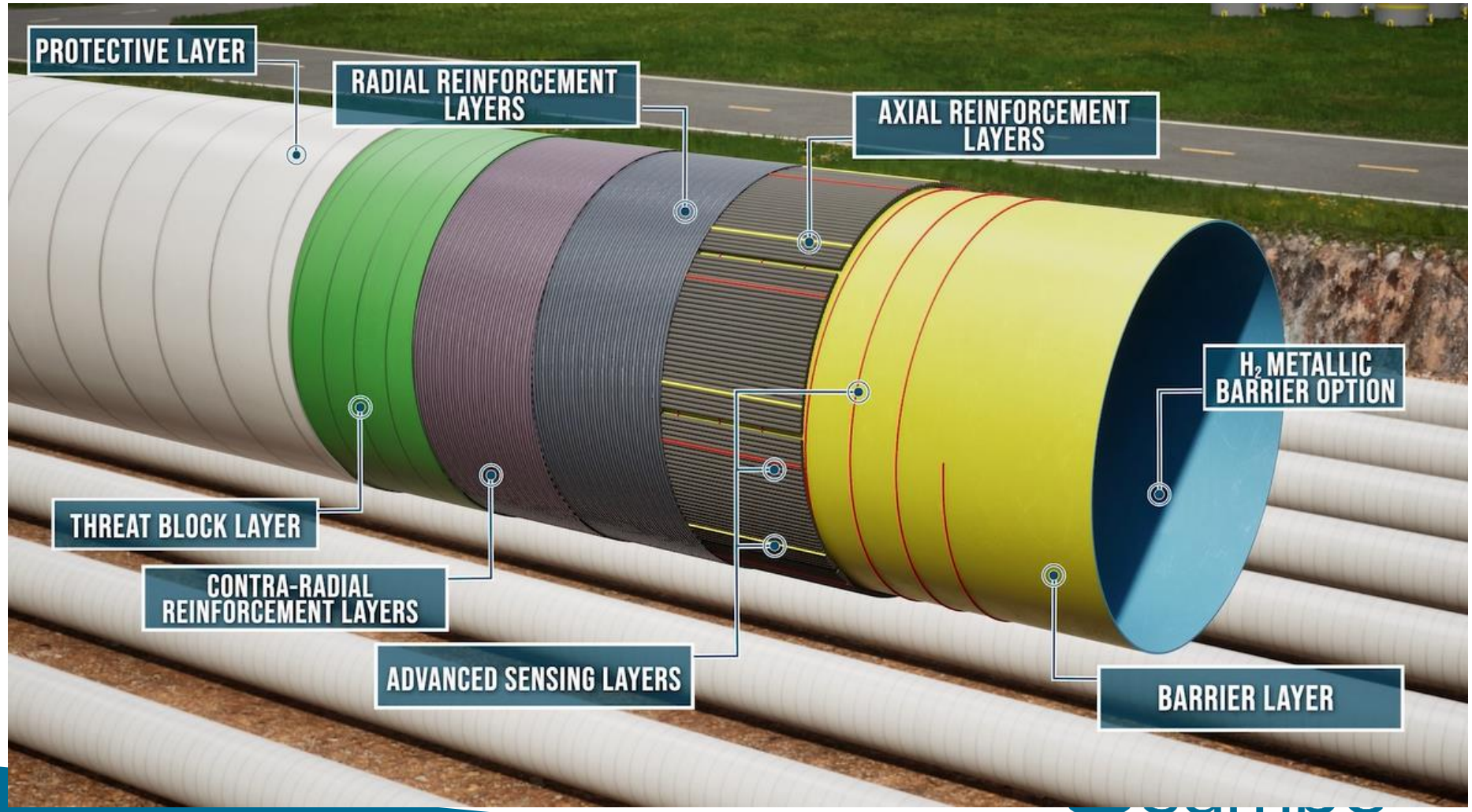
***Innovation Highlights***

**MicroRope™ Reinforcement:**
2.5x the breaking load of contemporary reinforcements

**Independent Axial and Radial Reinforcement:**
Increased pressure ratings, reduction in cyclic fatigue while increasing design life

**Elastomeric Resin:**
Eliminates the potential for resin microfracture due to cyclic, strain/fatigue, and impact events that occur in rigid carbon fiber vessels

**Permeation Resistance:**
Novel barriers radically minimize permeation of gases such as H2



# Key Design Considerations

## MicroRope™

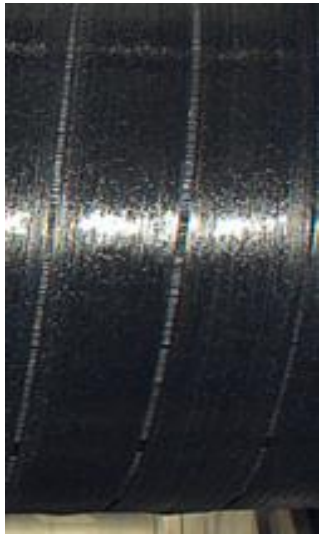
- Provides product structural integrity
  - E.g., resistance against internal pressure
- Novel design (tows in torsion) equals higher pressure rating at lower costs

## Separation of Function

- Layered designed allows for optimization based on application, for example:
- Thermoplastic specifically designed for chemical resistance
- Application of MicroRope designed specifically for pressure rating
- Threat block layer for defense applications

## Angle of Reinforcement

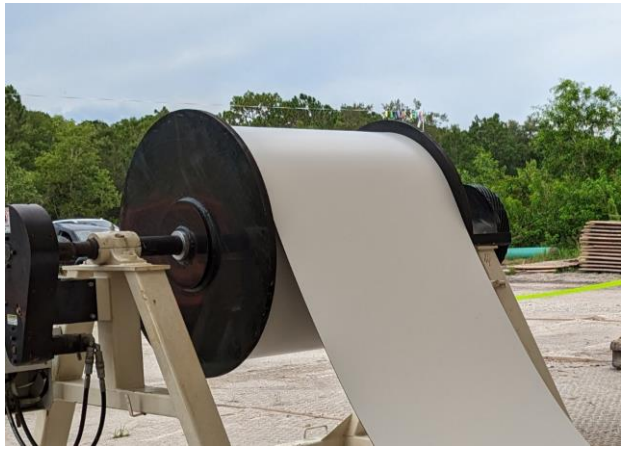
- Design allows for an aggressive angle of radial and contra-radial windings
- Increases overall integrity while reducing the total reinforcement required



# Thermoplastic Layer

## Materials formulated specifically for hydrogen applications

- Highly permeation and diffusion resistant cylinder liner
- Novel β-SiC/aluminum alloy extruded into MDPE
- Specialty alloy foil fused to the ID of our vessels
  - Contemporary systems apply permeation barriers to the OD of the vessel
- Restricts hydrogen from penetrating into amorphous region
  - Lowers risk profile for long-term operation

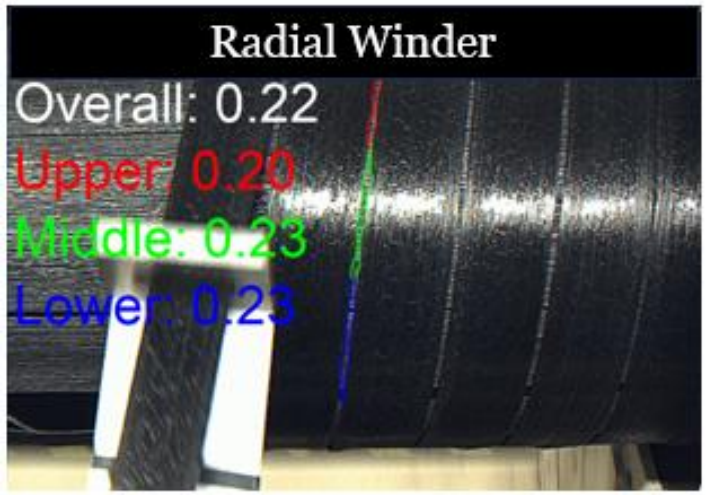


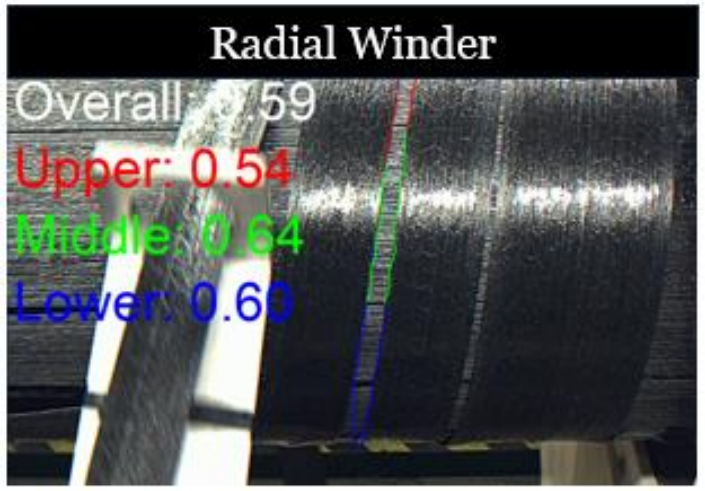
MDPE trial with TiO2 layer for permeation resistance

# Advanced QA/QC

## Following ISO 9000 Series

- Real-time data evaluation with emphasis on highest risk areas
- Vision systems for weld seam and MicroRope™ spacing confirmation
  - Real-time weld quality tracking
  - Monitoring spacing between layers
  - Evaluated entire system post MicroRope™ install
  - Integration of results with ITC design calculus to report real-time product quality
- Manufacturing data aligned with real-time health and risk monitoring system to accelerate product iterations

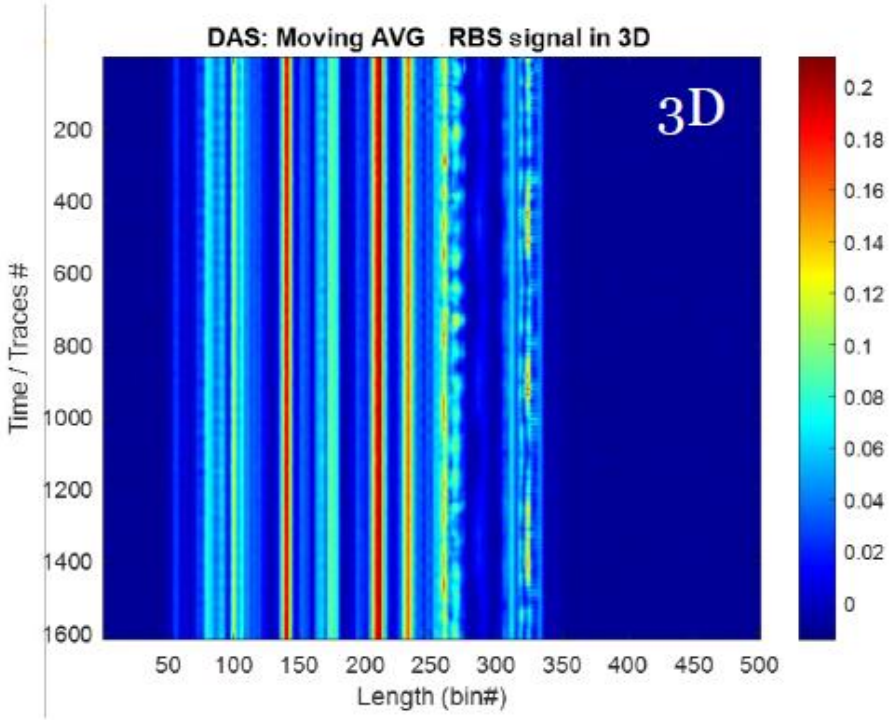


# Health and Risk Monitoring System

**HRMS**

- Sensors embedded during the manufacturing process
- Continuous interrogation of the ITC with ML based event classification and localization
  - Impacts, ground quality, third-party threats, strain, flow, pressure, temperature, leaks
- Operational systems architecture
  - Field-deployed A.I./ML edge computing for light-weight classification
  - Cloud-based storage and modeling for classification refinement
  - Cloud-based threat notification for site operators




Distributed Acoustic Sensing of impact event on pipe generated during HRMS validation testing

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# HRMS

## Real-time Monitoring

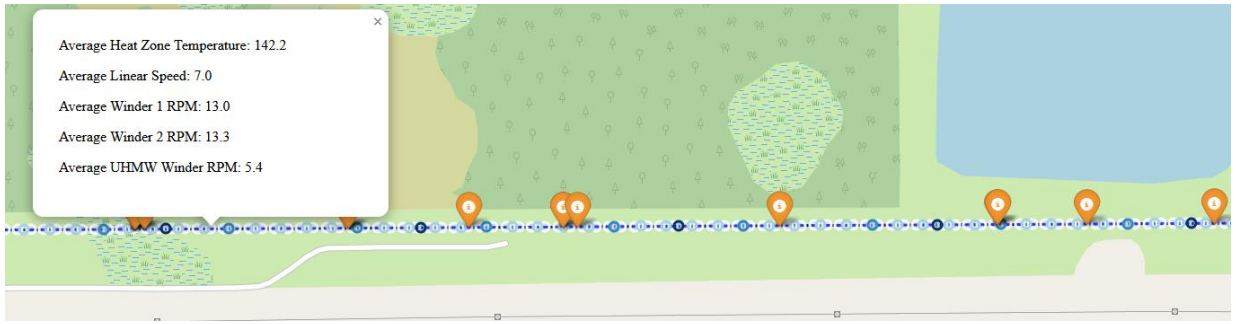
- Embedded fiber optic sensors between the thermoplastic and MicroRope layers provide optimized in-situ product health
- Resolution to less than one meter means that planned maintenance activities can be done efficiently and cost effectively

## Reduced OpEx, Reduced Liability

- Continuous data monitoring ensures end-users that their asset is always protected and provides operators the data necessary to avoid unplanned outages

## Continuous Product Optimization

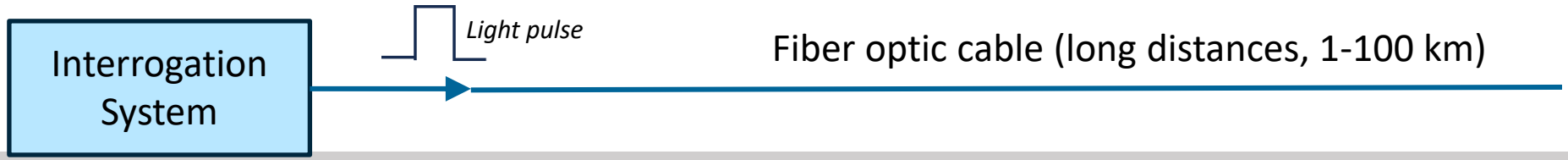
- Connecting advanced QA/QC manufacturing data with real-time operation and monitoring data ensures that the product is always optimized for the application and site



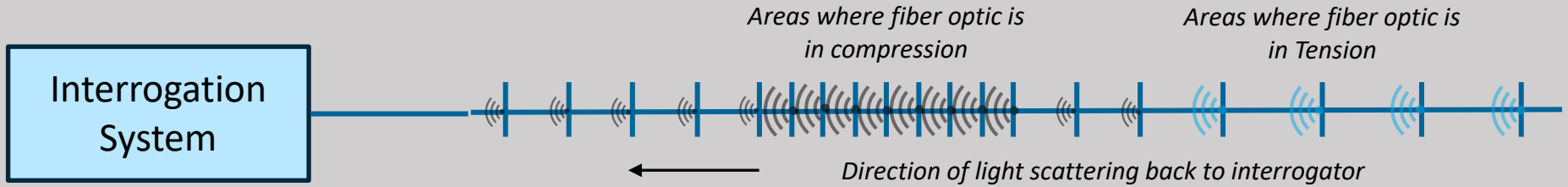
# HRMS – Fiber Optics

Fiber optic interrogation is both simple and complex, with relatively complex optical physics being leveraged to implement relatively simple instrumentation methods that have major advantages over traditional sensors.

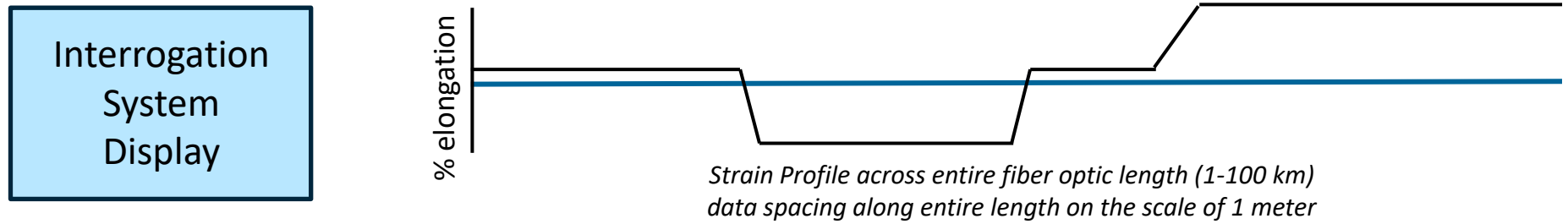
Step 1: Interrogation system sends a laser light pulse down a fiber optic cable




Step 2: Light interacts with the cable and some scattered light comes back to the interrogator. The signal coming back is a function of the strain environment in the cable.




Step 3: The transit time and intensity of the scattered light is precisely measured, providing measurements along the entire fiber optic cable length

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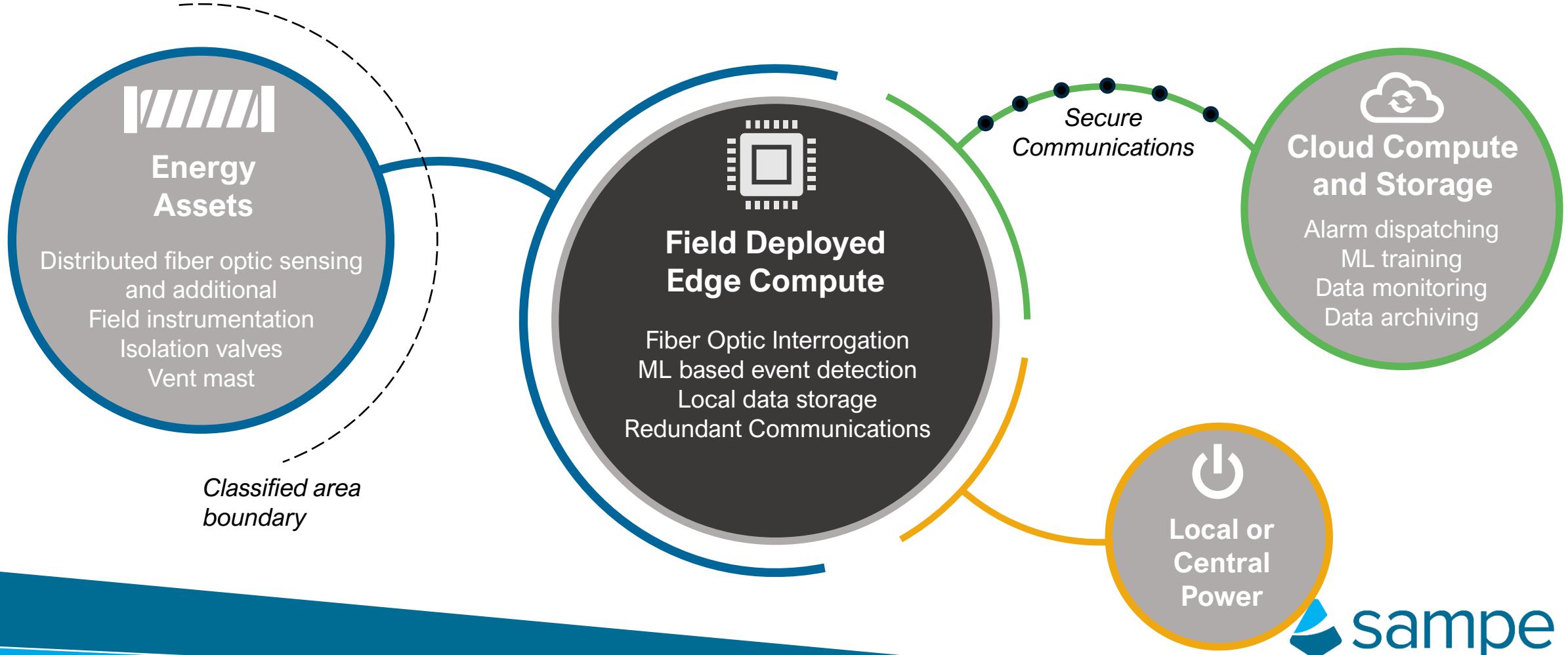
# HRMS - Integration



# Full-Scale Testing

**Gaps in Regulations/Codes & Standards often lead to the need for more comprehensive test programs**

- Designing and building our own full-scale test platforms for hydrogen, natural gas, and other fuels
- Recently patented a full-scale test setup for any size pipe or vessel
  - Build in-progress, online Fall of 2024
- Need facilities that can do full-scale testing that isn't qualification testing

1.3-mile-long, 16" ITC installed during pilot program with strategic partner.

# Advantages of Working with BrainDrip

**Made in the U.S.A.**

- Manufacturing and operations facility in Jacksonville, Florida
- Testing, interrogation, and compliance in Denver, CO
- Ability to source 100% of materials within the U.S.

16” ITCs at field site during demonstration project

# Contacts

Thank you!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