EPIC Meeting for Fibre Sensors-
Creating Smart Parts with Lifetime Fibre Sensors

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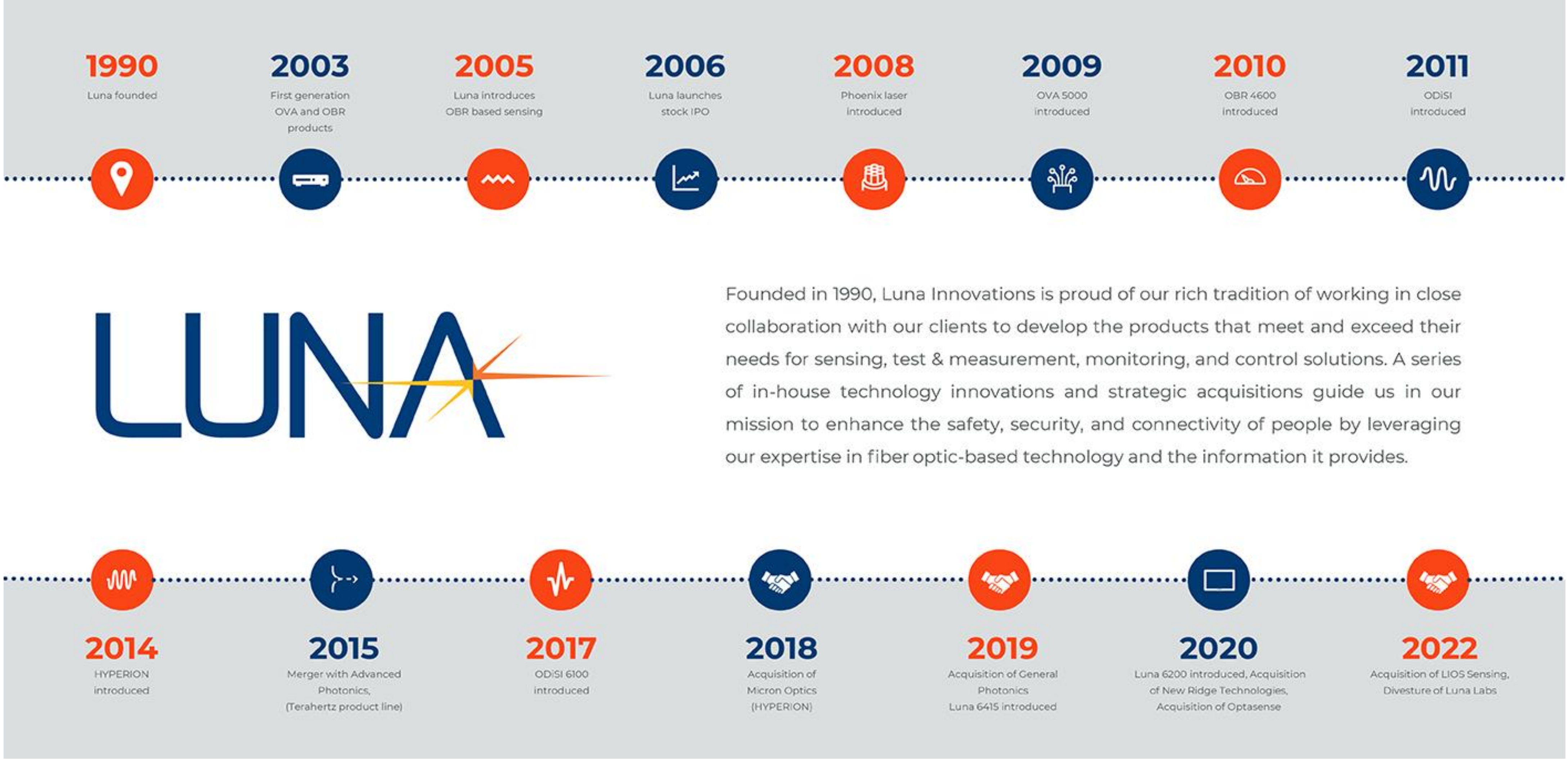
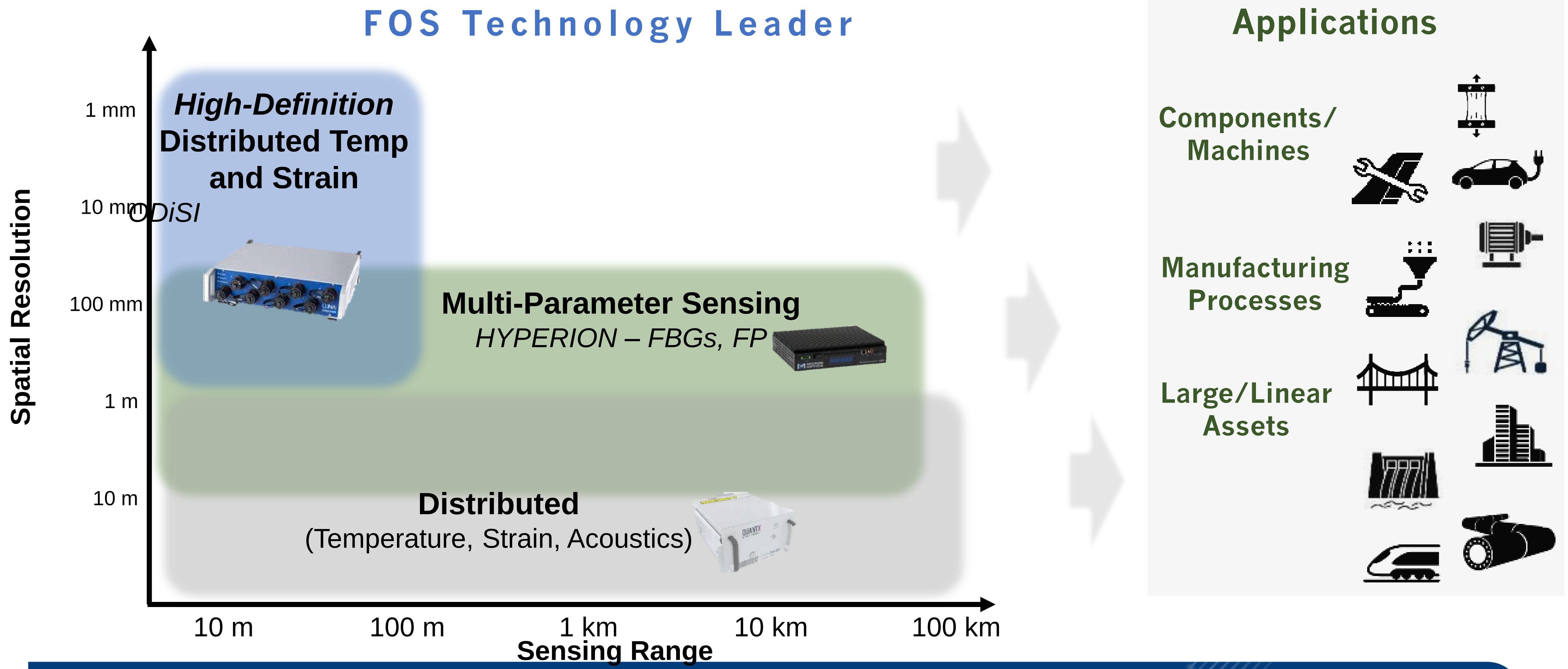
April 2023

Overview



1990
Luna founded
2003
First generation OVA and OBR products
2005
Luna introduces OBR based sensing
2006
Luna launches stock IPO
2008
Phoenix laser introduced
2009
OVA 5000 introduced
2010
OBR 4600 introduced
2011
ODiSI introduced
LUNA
Founded in 1990, Luna Innovations is proud of our rich tradition of working in close collaboration with our clients to develop the products that meet and exceed their needs for sensing, test & measurement, monitoring, and control solutions. A series of in-house technology innovations and strategic acquisitions guide us in our mission to enhance the safety, security, and connectivity of people by leveraging our expertise in fiber optic-based technology and the information it provides.
2014
HYPERION introduced
2015
Merger with Advanced Photonics, (Terahertz product line)
2017
ODiSI 6100 introduced
2018
Acquisition of Micron Optics (HYPERION)
2019
Acquisition of General Photonics
Luna 6415 introduced
2020
Luna 6200 introduced, Acquisition of New Ridge Technologies, Acquisition of Optasense
2022
Acquisition of LIOS Sensing, Divesture of Luna Labs

Luna Fiber Optic Sensing Technology Landscape



Fiber-Optic Sensing Instruments and Sensing Solutions

- Up to **100km** data output
- 1m output channel pitch (2m in 100km mode)
- **High-sensitivity** and **low noise floor** for **quantitative** acoustic, strain and temperature monitoring (mK/με)
- Proprietary Rayleigh measurement technique

DAS

- **Long Range distributed temperature and strain**
- Sampling interval down to **0.25 m**
- It can be configured with one, two, or four channels each providing up to a 100 km range (6 km for a four-channel configuration).
- Raman and Brillouin sensing technology

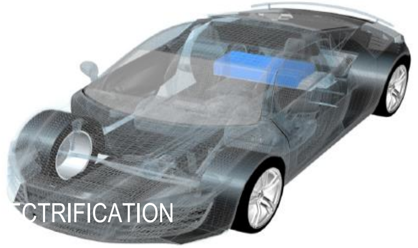
DTS/DSS

- Up to 16 parallel channels per system with 10's of km range
- Multipoint, **multi-parameter sensing with 1 pm accuracy**
- Proven reliability and longevity, with **over 100 million hours** logged since 2000
- **160 nm, full spectrum measurement** for FBG and FP based sensors

HYPERION

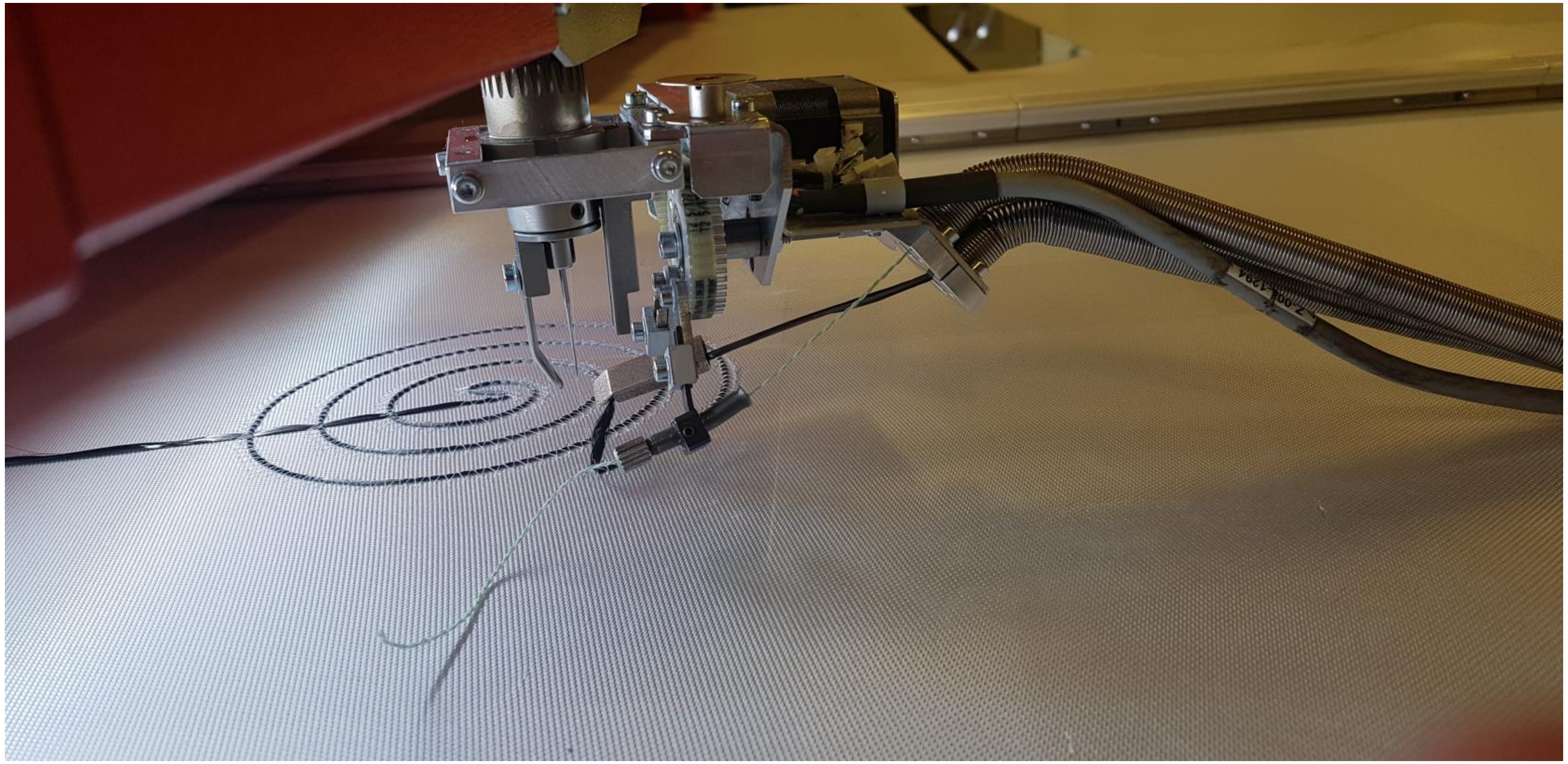
- Multichannel measurements - up to 8 channels per system
- **Up to 100 m of high-definition sensing per channel**
- Measure and acquire strain and temperature with a spatial resolution **as dense as 0.65 mm – 1000's of sensors**
- Optical Frequency Domain Reflectometry using Rayleigh scattering.

ODiSI



Case Study - Feasibility of intelligent workpieces in composite manufacturing

- Use TFP Machine to install fibre sensor during weaving
  - Demonstrate performance of sensors for:
    - Resin injection
    - Resin curing
    - Machining (drilling and slotting)



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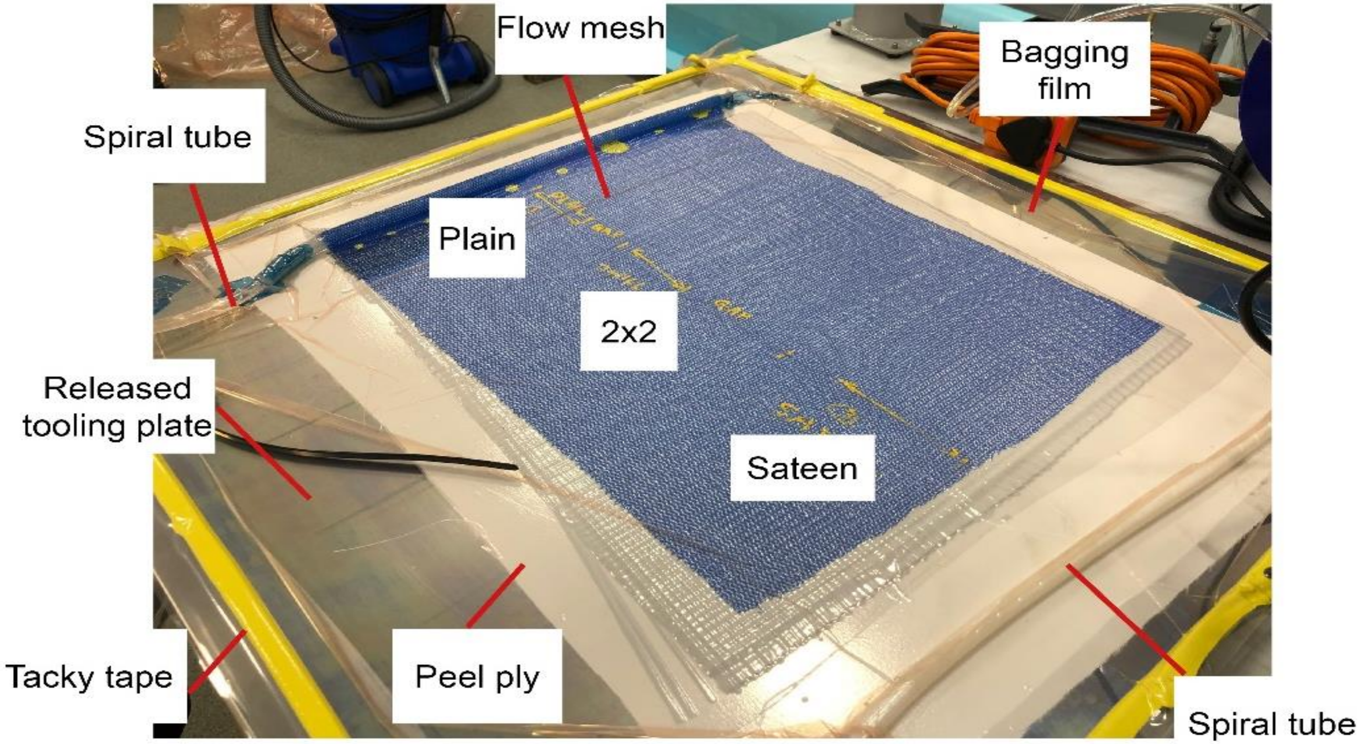
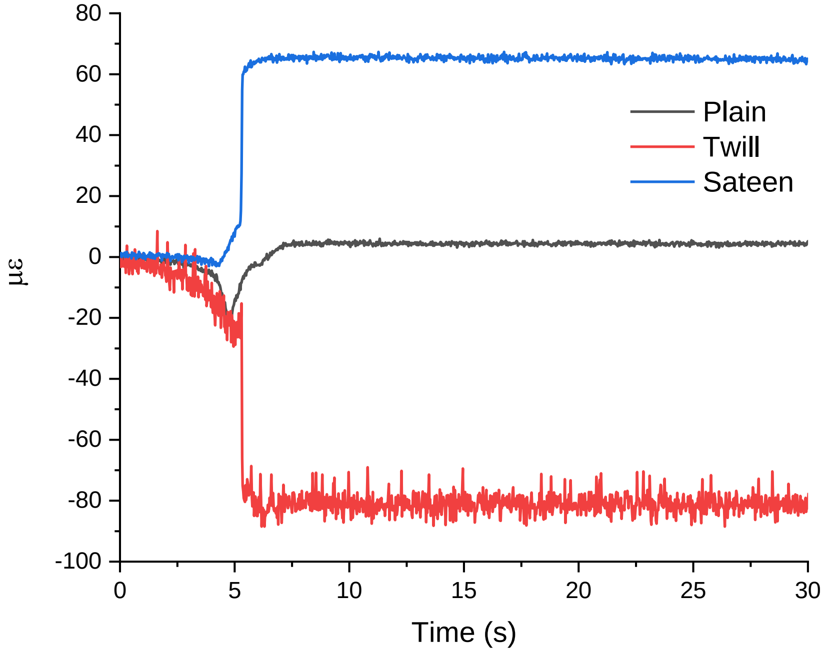
Case Study -VARTM Infusion – Vacuum Bed Release



VARTM layout for Dornier woven material for 3 weave styles with fibre optic sensor laid across the different fabric styles



Strain change following vacuum bed release

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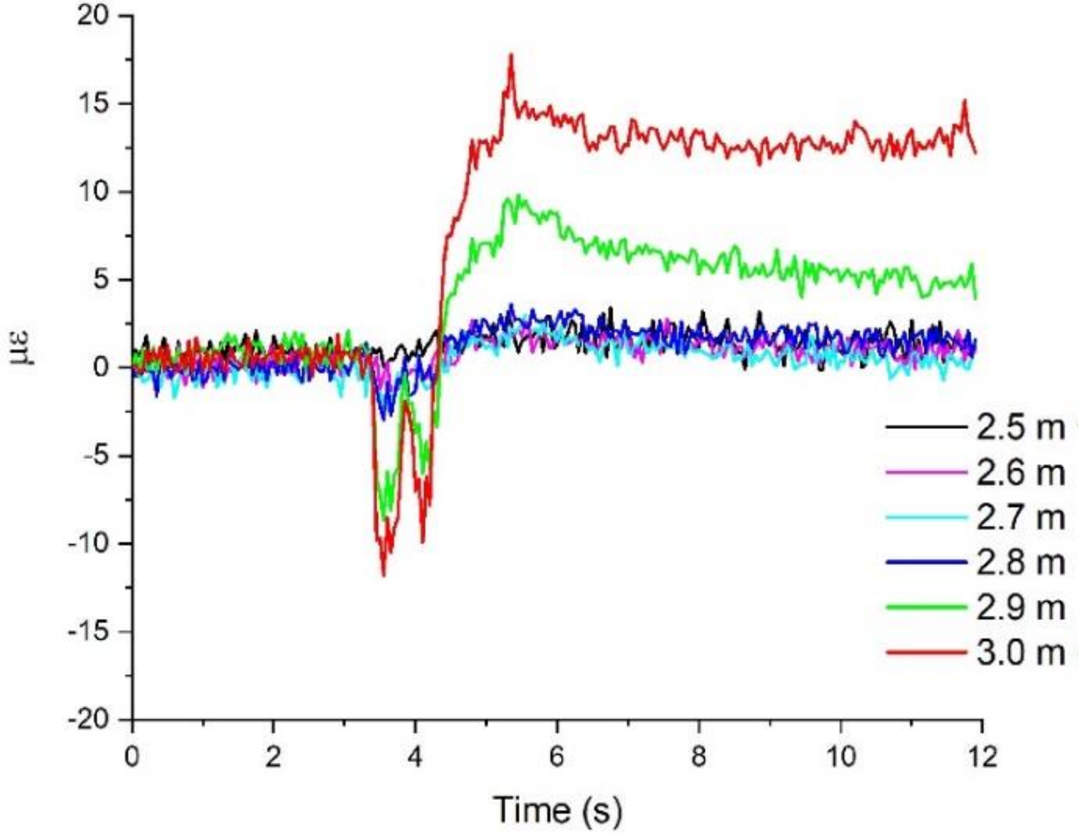
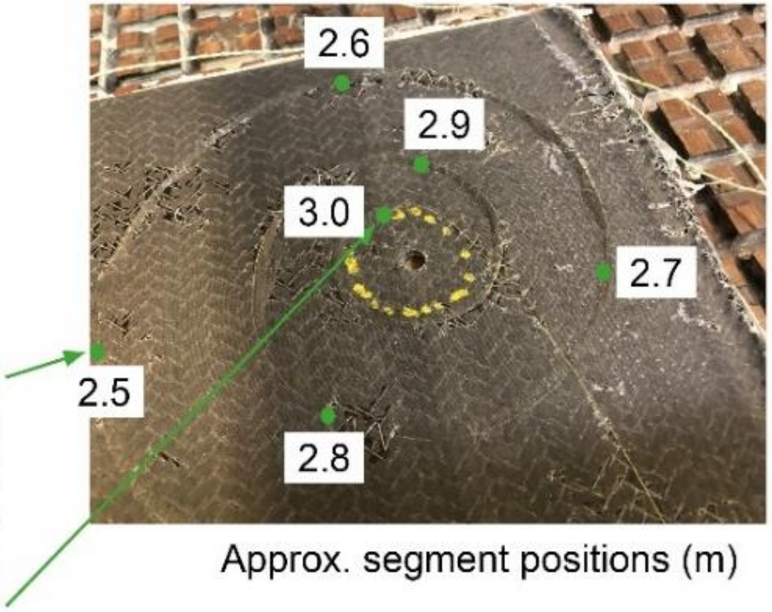
Case Study Machining - Drilling





Approx. segment positions (m)

Results of 6 mm Ø drilling inside TFP final spiral

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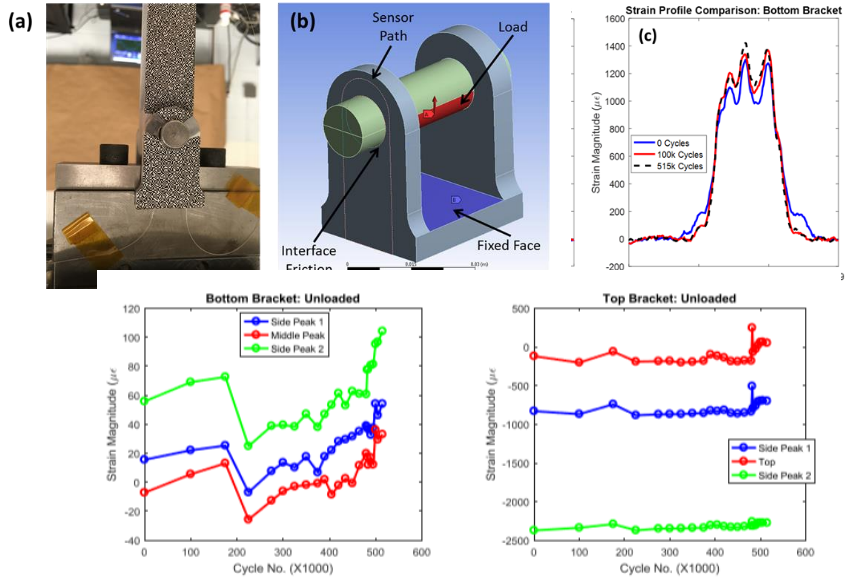
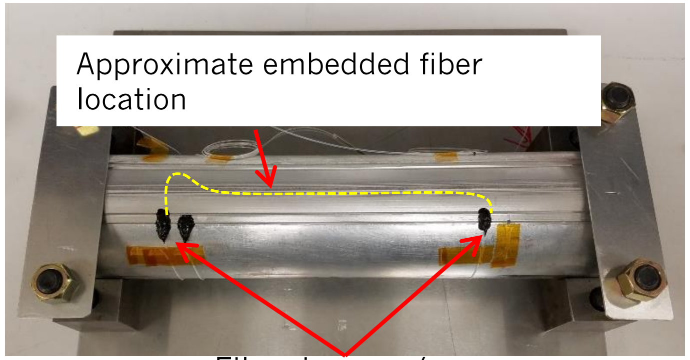
Smart Parts through Additive Manufacturing

- Luna worked with Fabrisonic to embed fiber into aluminum parts using ultrasonic additive manufacturing
- First part was to determine where and when a clevis joint began to fail from cyclic fatigue
- Part was cycled 515K times and intermittently checked for failure
- Data compared to FEA model and used to refine boundary conditions



- On a NASA funded effort the team is developing a pipe section to measure distributed temperature
- Fiber is embedded into a section of pipe during manufacturing
- Enables temperature and heat flux to be determined from the temperature and strain measurement

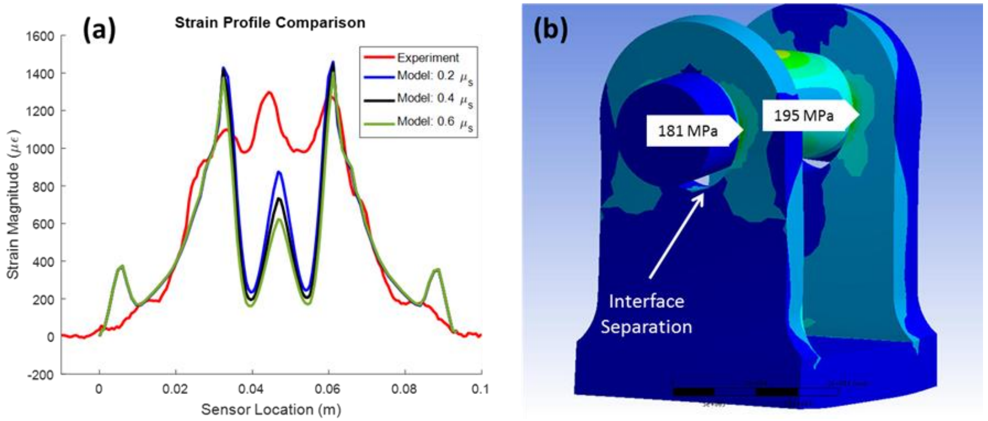


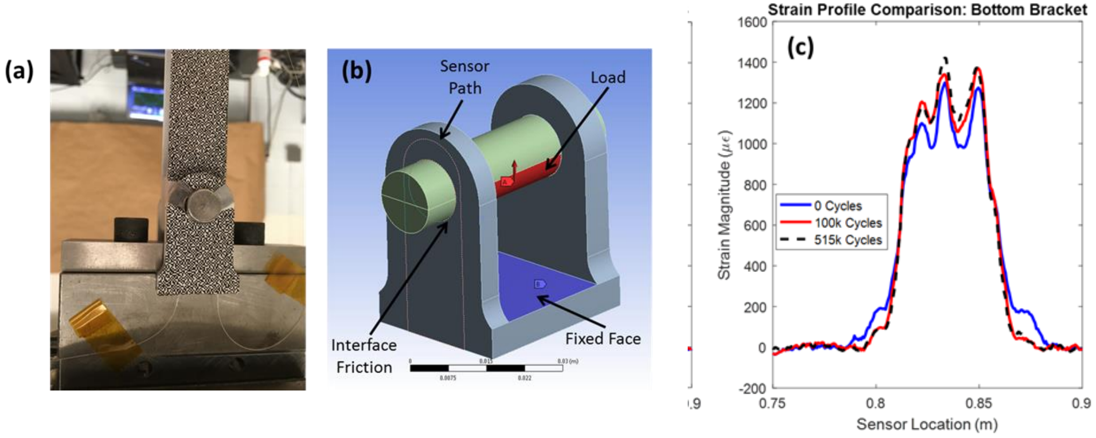
Fiber ingress/egress

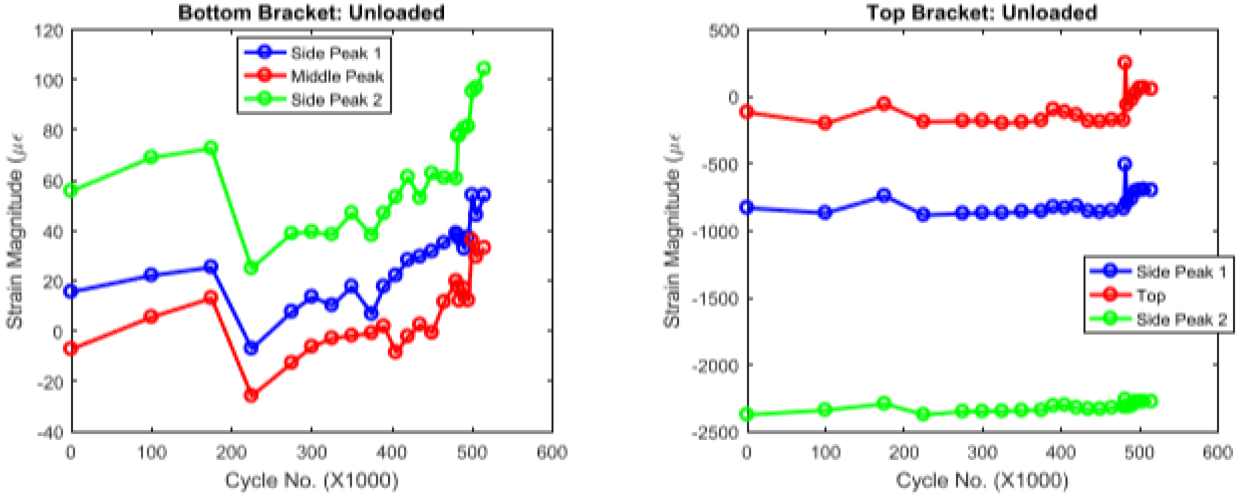
FABRISONIC

Model Validation of a Pin Joint

- Embed fiber into aluminum parts using ultrasonic additive manufacturing
- Part was cycled 515K times and intermittently checked for failure
- Data compared to FEA model and used to refine boundary conditions
- Differences in modeled behavior attributed to:
  - The sensitivity of the bracket to different friction values
  - The model not adequately describing the interface coupling between the pin and bracket.







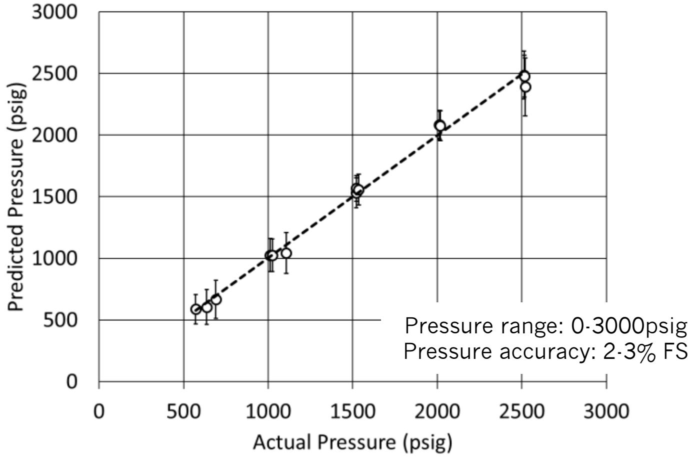
Hehr, A., Norfolk, M., Sheridan, J. et al. "Spatial Strain Sensing Using Embedded Fiber Optics". JOM (2019) 71: 1528. https://doi.org/10.1007/s11837-018-3297-y

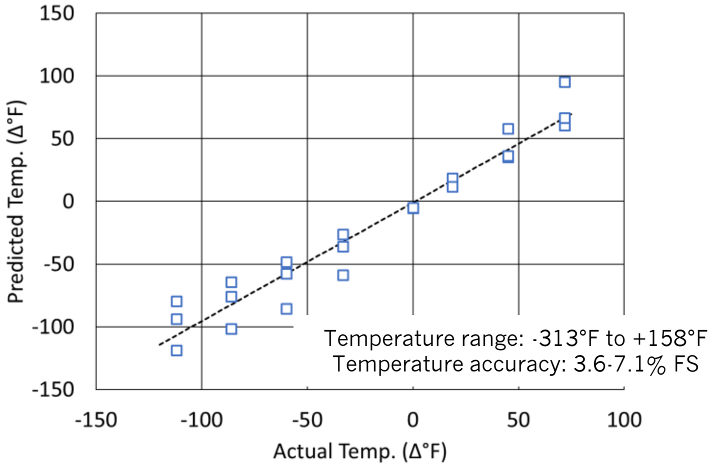
Embedding into Piping Sections

- Objective was to gather data in cryogenic fuel pipes for rocket test stands
- Luna strain sensors embedded in a 3D printed pipe wall to measure pressure, temperature and heat flux.
- The pipe was tested at various pressures and temperatures to calibrate the sensor, including boiling the pipe in water and filling it with liquid nitrogen.
- Throughout the tests, the pipe continued to provide reliable data.

https://3dprintingindustry.com/news/fabrisonic-embeds-sensors-in-nasas-rocket-fuel-piping-using-3d-printing-166314/

Prototype Pressure and Temperature Responses





Thank you – Questions?

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