



# ADVANCED DEEPWATER MONITORING

# FAILURES TO MONITOR AND PREDICT

- Detect early warning signs
- Automate monitoring of critical systems
- Give critical data to key decision makers



**Deepwater Horizon**  
2010



**Thunder Horse**  
2005



**Texas City Refinery**  
2005

# ABOUT **ASTRO TECHNOLOGY**

## ADVANCED INSTRUMENTATION FOR:

- Subsea fields
- Pipelines and risers
- LNG facilities



## **ENGINEERING CAPABILITIES INCLUDE:**

- System integration
- Real-time embedded systems
- Experimental stress analysis
- Fiber-optic sensor technology
- Conventional sensor integration
- Environmentally hardened systems
- Software development

# DEVIL'S TOWER BASS LITE (OMAE 2012)



- Located in Atwater Valley Block 426
- Utilizes 20.3-cm (8-in) diameter flowline
- 90-km (56-mi) length
- Ties to Devil's Tower in Mississippi Canyon
- Production – Up to 130 million cubic feet per day
- Water depth – 2,050 m (6,750 feet)
- Commenced operation in February 2008

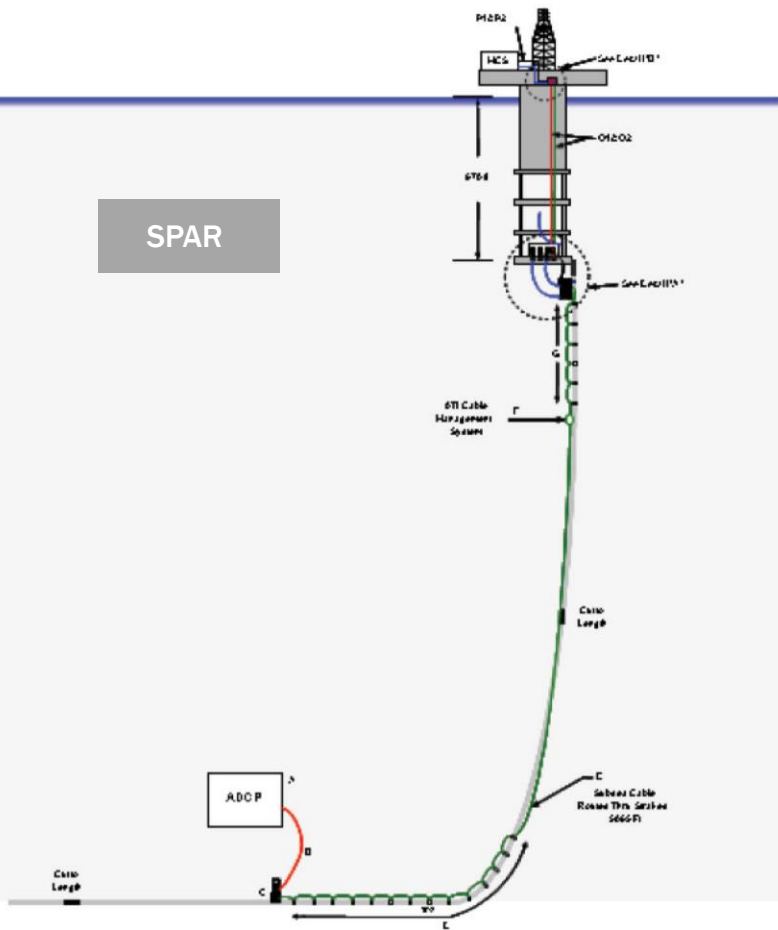
### MONITORING:

- Pressure
- Temperature
- Hoop and Axial Strain

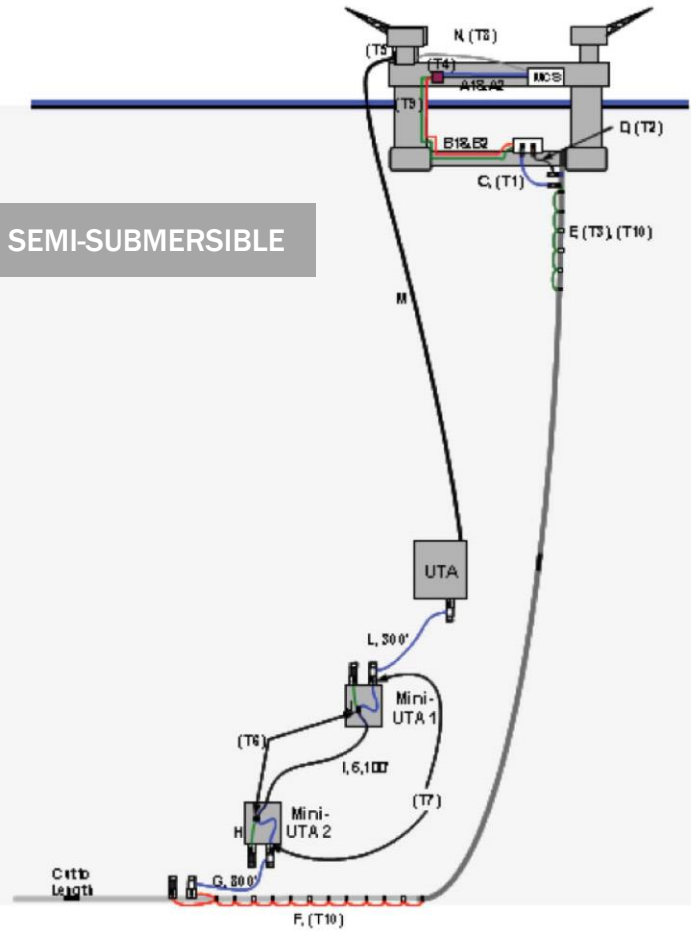


# PREVIOUS INSTRUMENTATION ON DEEPWATER RISERS

SPAR

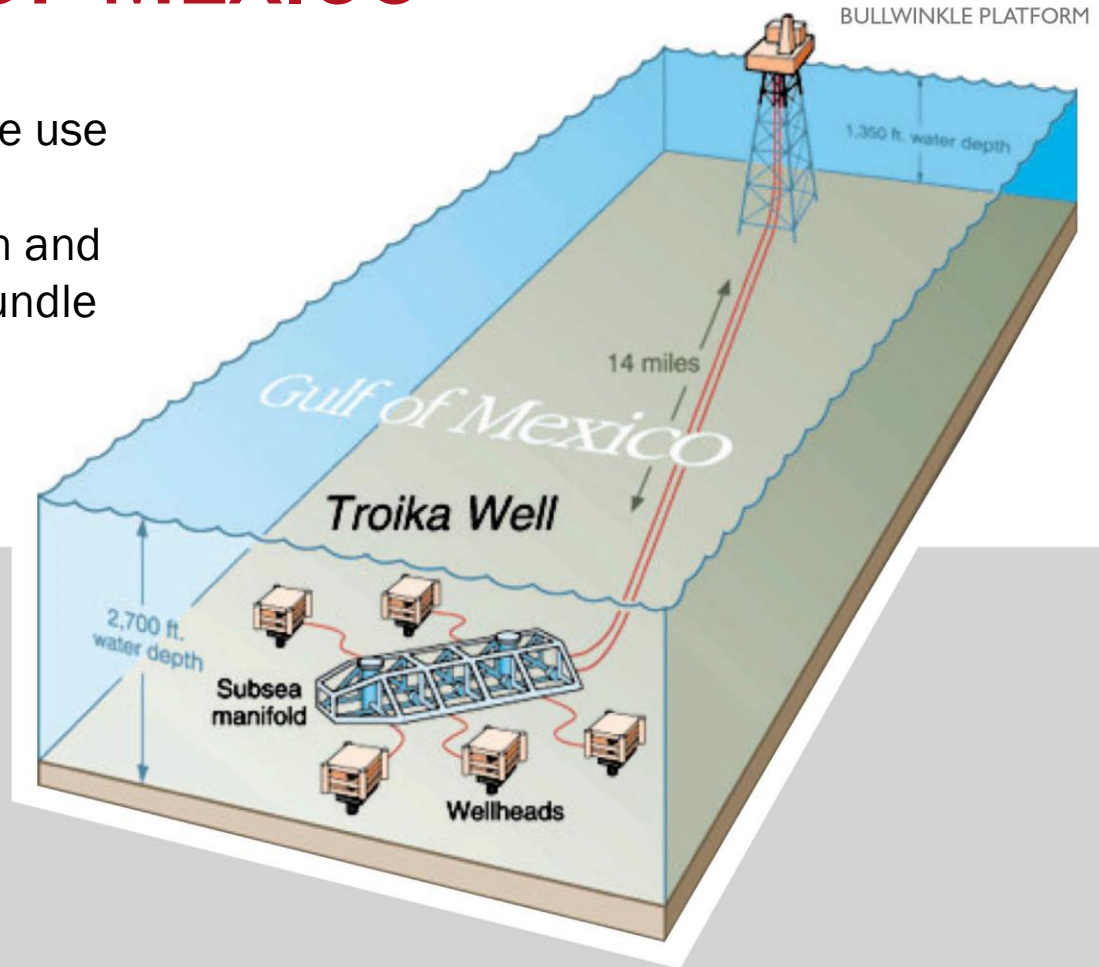


SEMI-SUBMERSIBLE

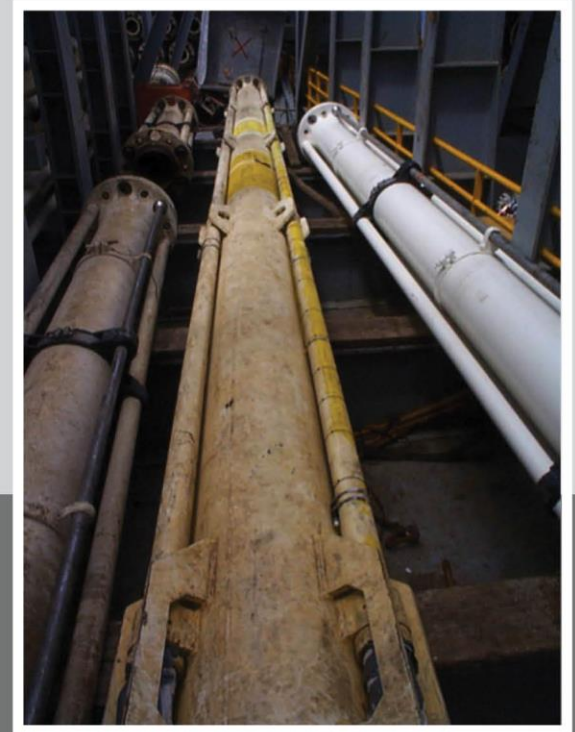


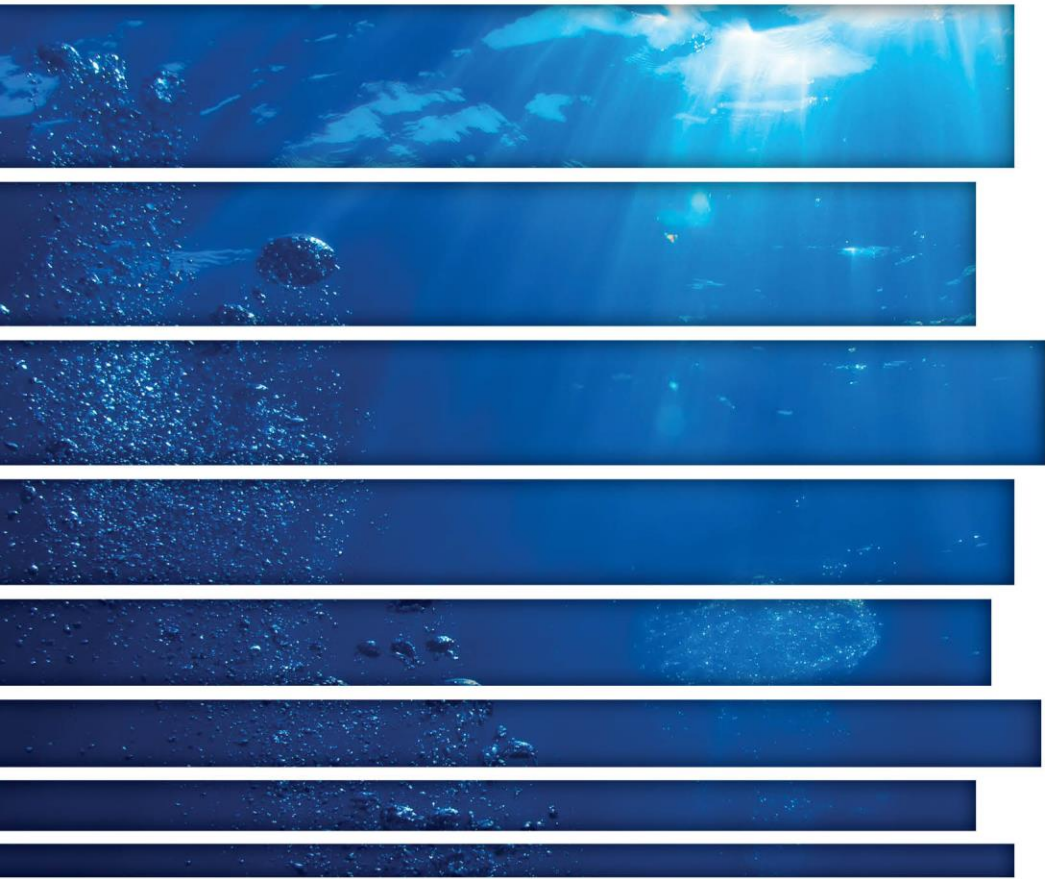
# TROIKA — GULF OF MEXICO

ASTRO TECHNOLOGY pioneered the use of fiber-optic sensors on a subsea pipeline to monitor pressure, strain and vibration in external casing pipe bundle during fabrication.



# FIBER-OPTIC SENSORS FOR DEEPWATER DRILLING OCEAN CLIPPER





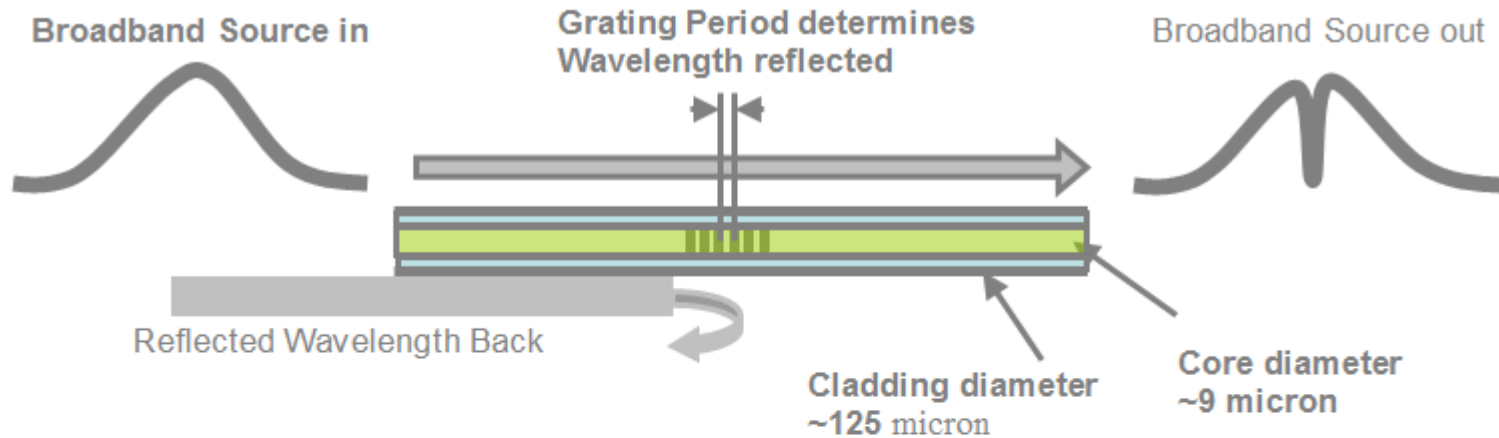
# OVERVIEW *of* INSTRUMENTATION METHODS



DEEPER INSIGHT.



# FIBER BRAGG GRATINGS



## Relationship between Strain ( $\epsilon$ ) and Change in Wavelength ( $\Delta\lambda_b$ )

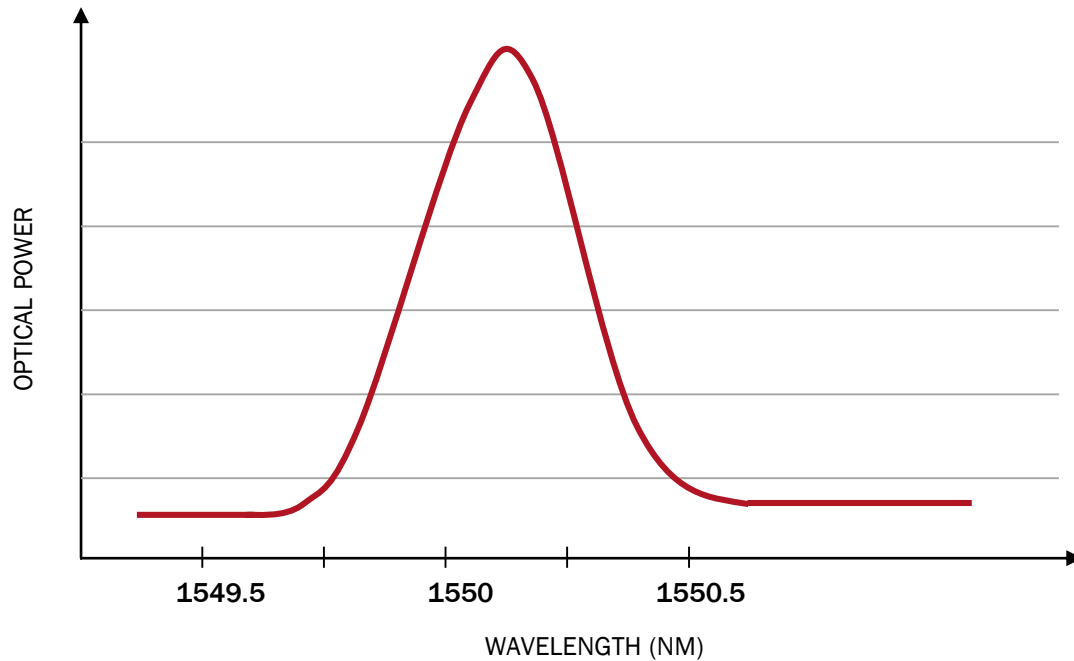
$\Delta\lambda_b / \lambda_b = (1-p_e)\epsilon$ , where  $p_e$  is the photoelastic constant for glass and  $\lambda_b$  is the base wavelength

Multiple Gratings (sensors) can be placed on a single fiber, enabling high sensor count per fiber channel.



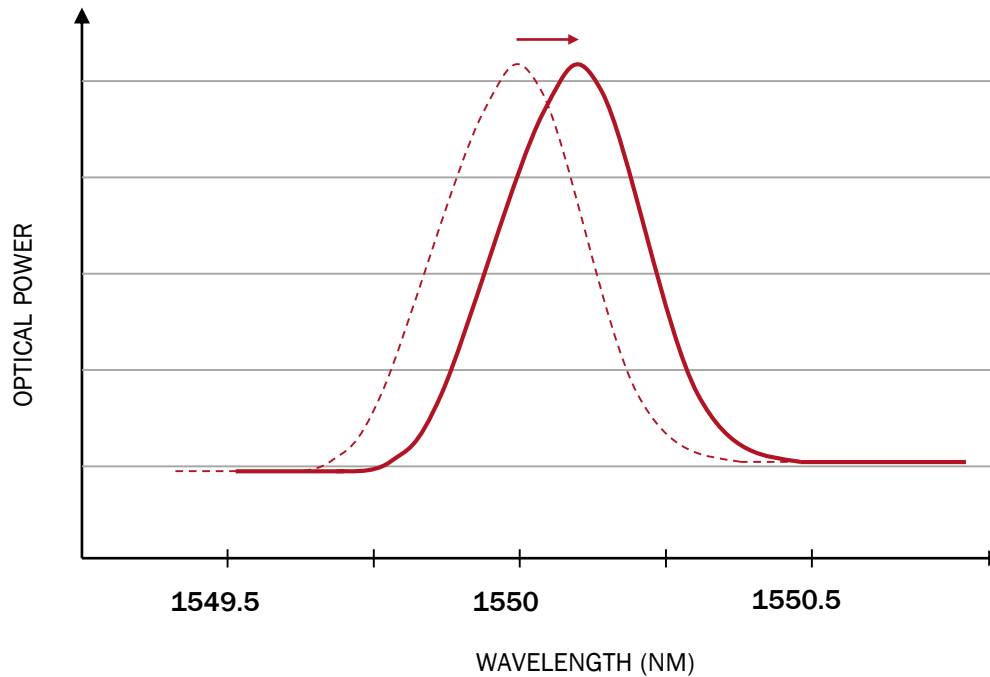
# RELATIONSHIP BETWEEN WAVELENGTH & STRAIN

## EXAMPLE BASE WAVELENGTH FOR A SINGLE FBG



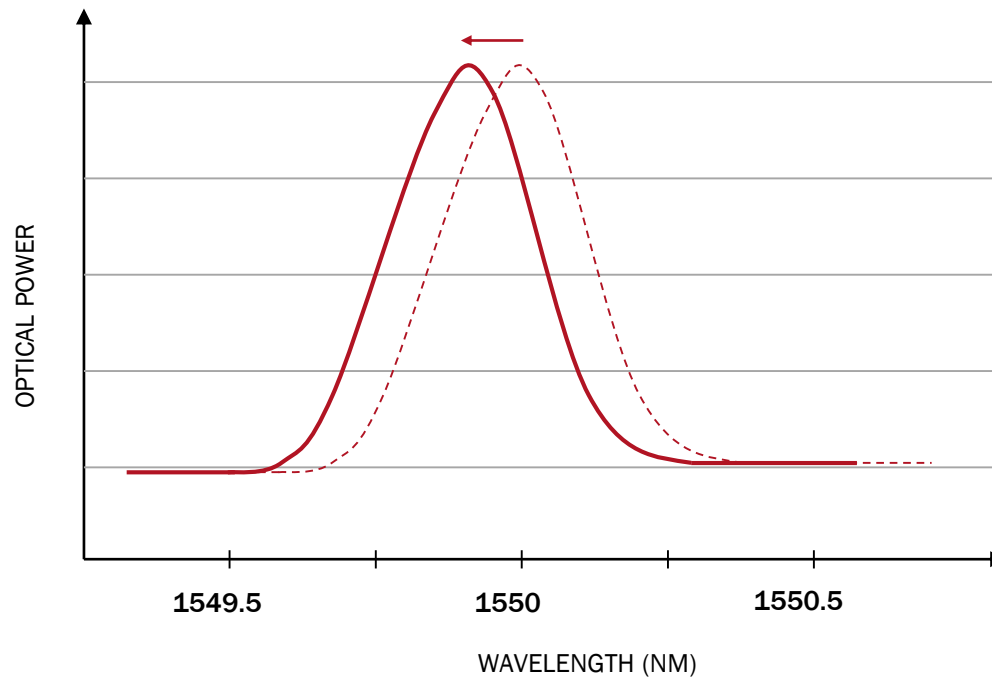
# RELATIONSHIP BETWEEN WAVELENGTH & STRAIN — TENSION

REFLECTED SIGNAL FROM THE PREVIOUS FBG IN TENSION

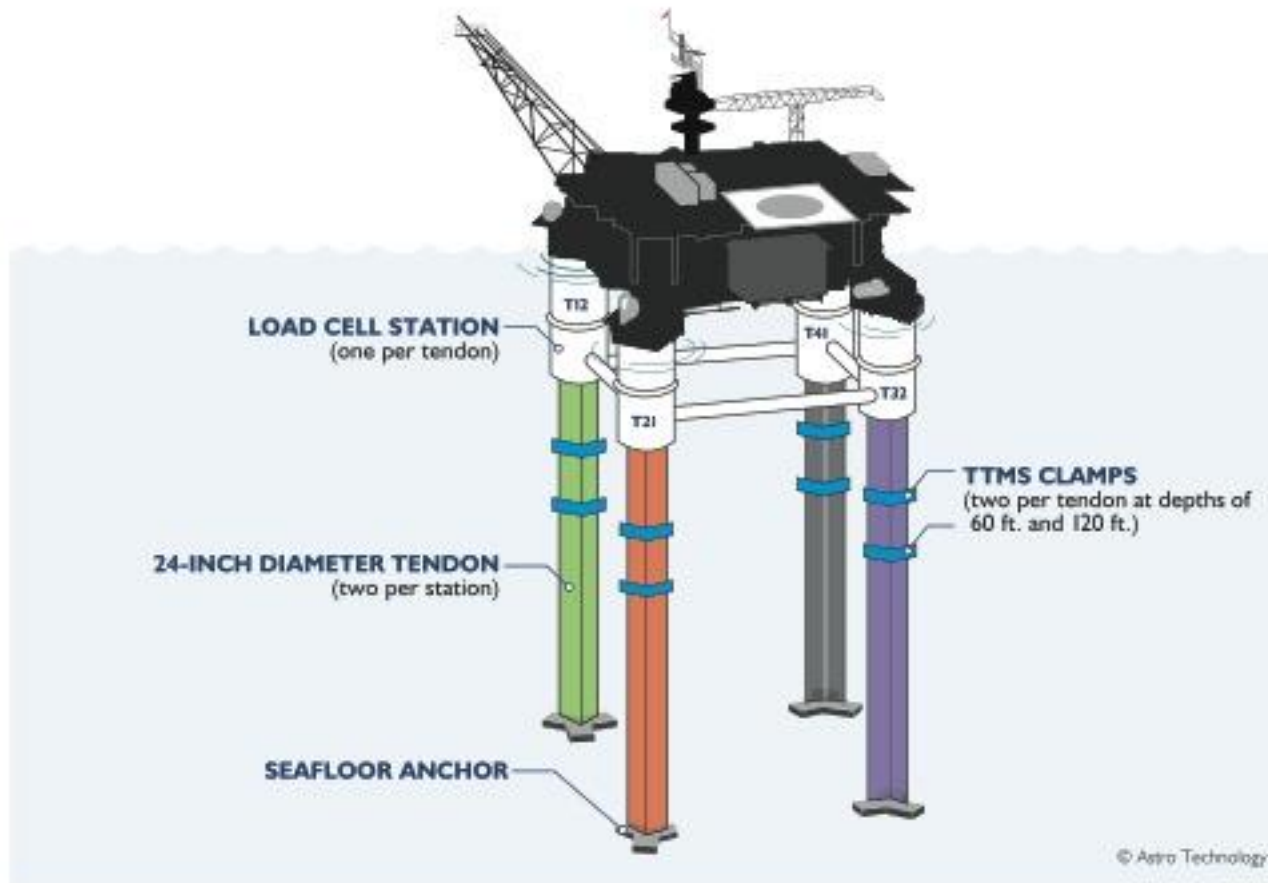


# RELATIONSHIP BETWEEN WAVELENGTH & STRAIN – COMPRESSION

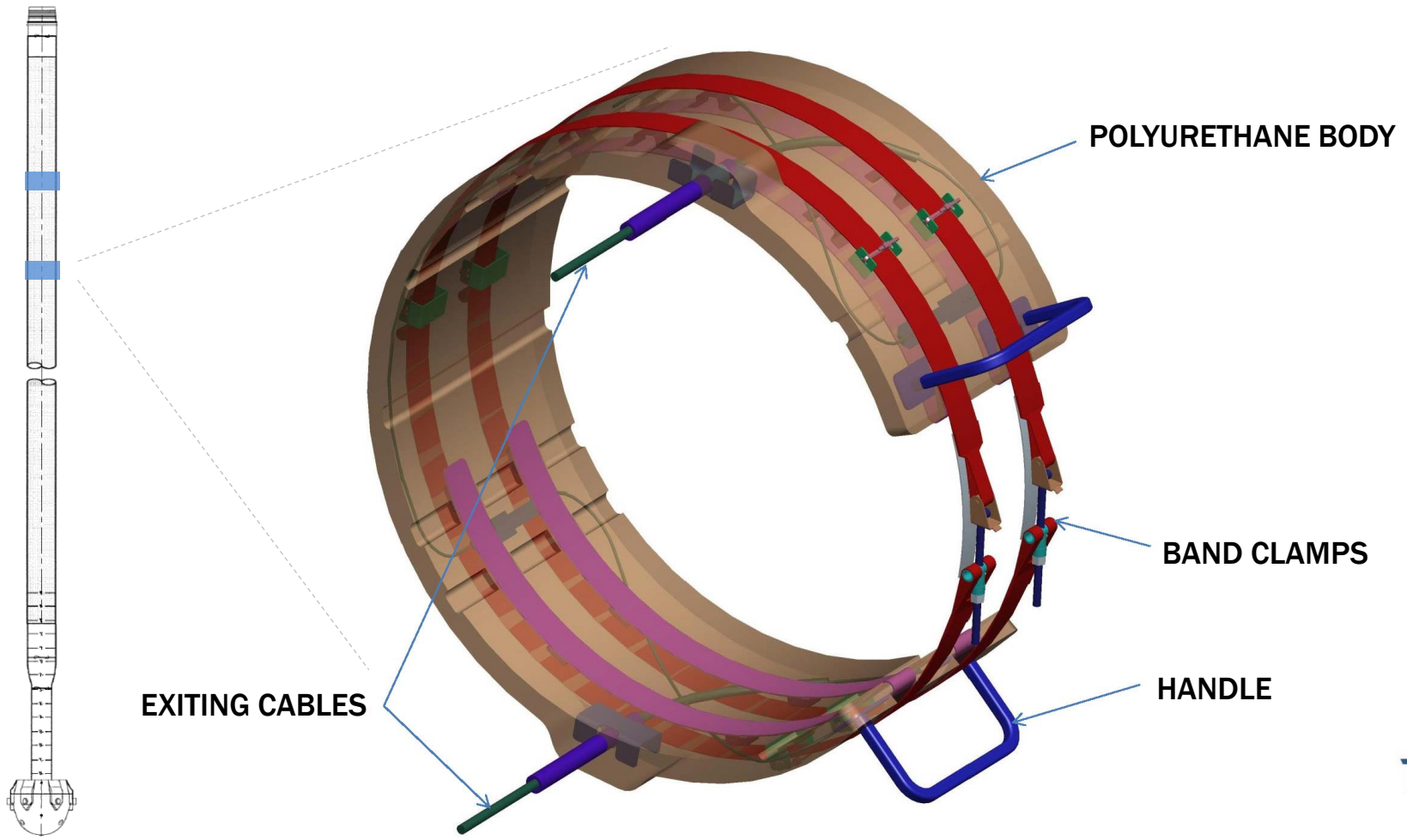
REFLECTED SIGNAL FROM THE PREVIOUS FBG IN COMPRESSION



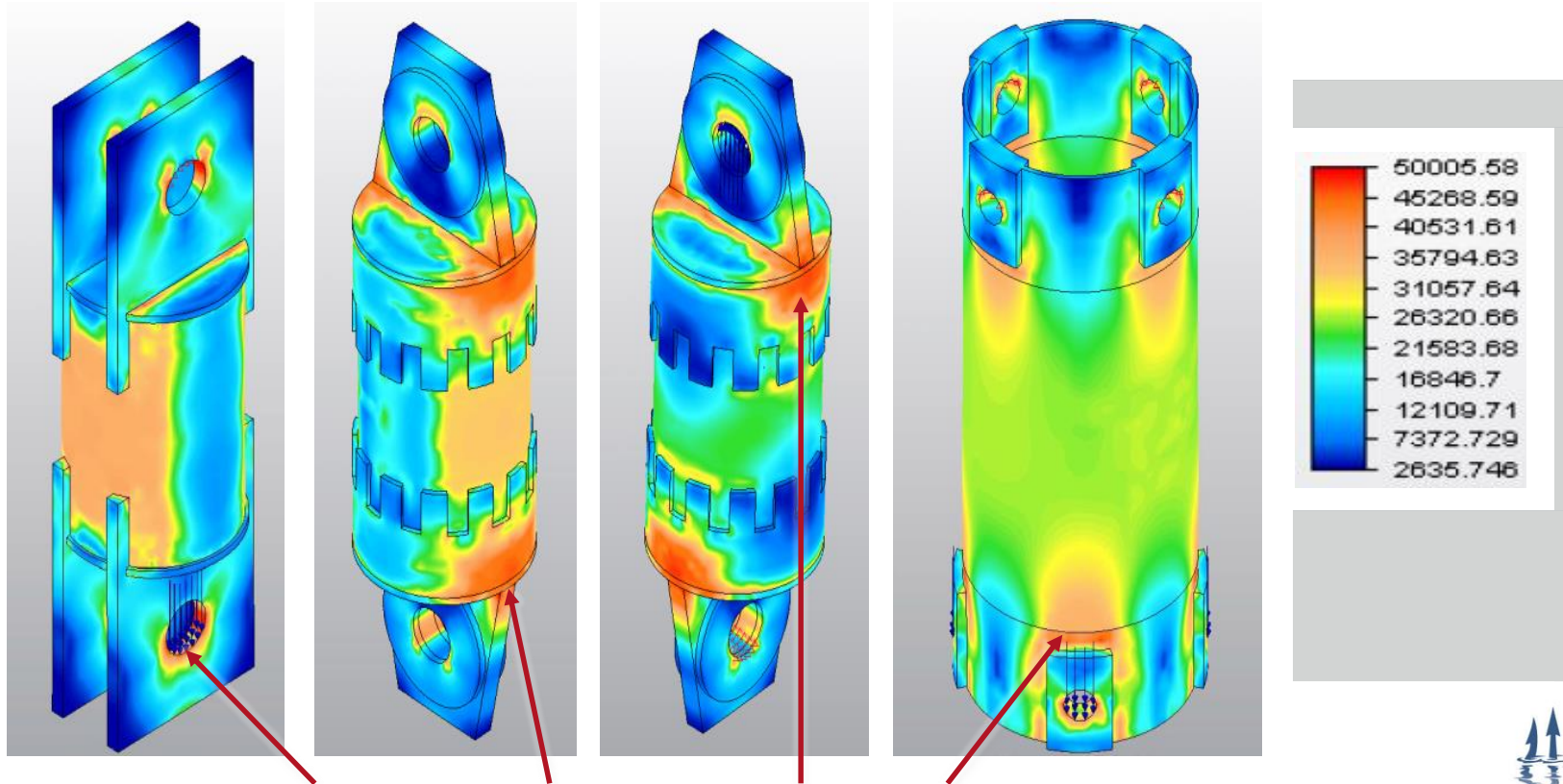
# TENSION LEG PLATFORM SENSORS



# TENDON TENSION MONITORING SYSTEM



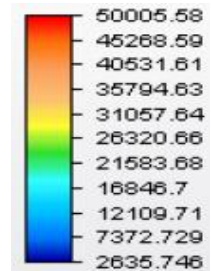
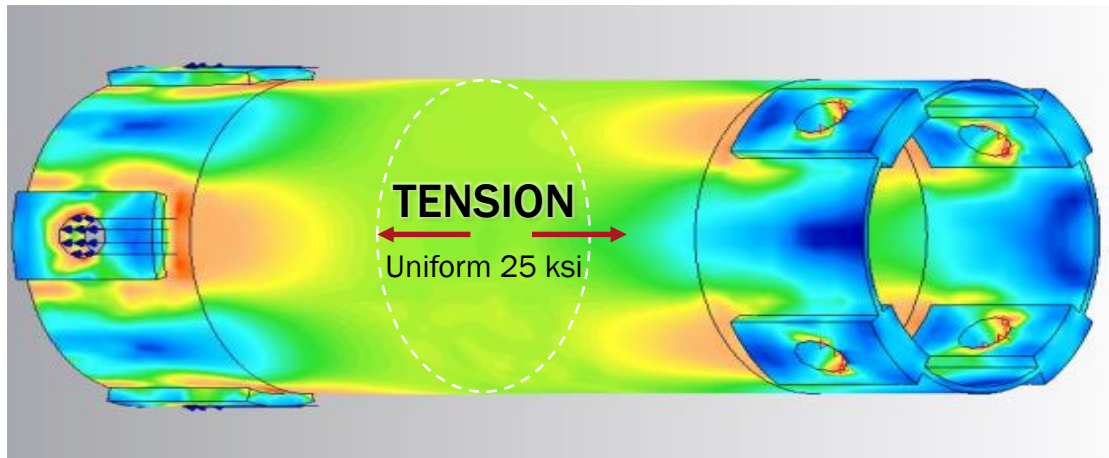
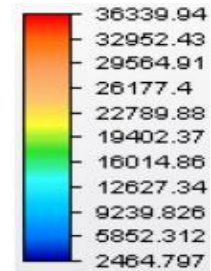
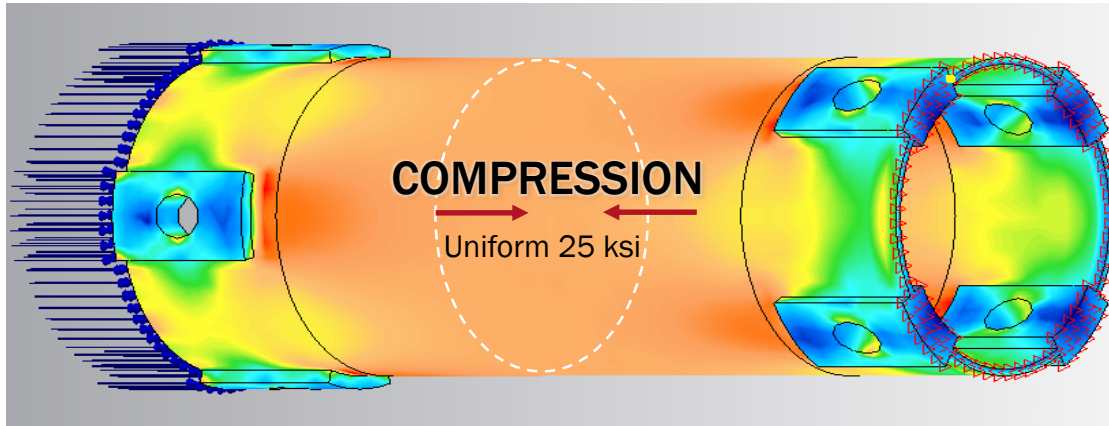
# ADHESION TESTING FOR SUBSEA INSTALLATION



**FEA TEST ARTICLE PIPE FOR TENSION TESTING**  
 Avoid Local Areas of Inelastic Deformation (>50 ksi)

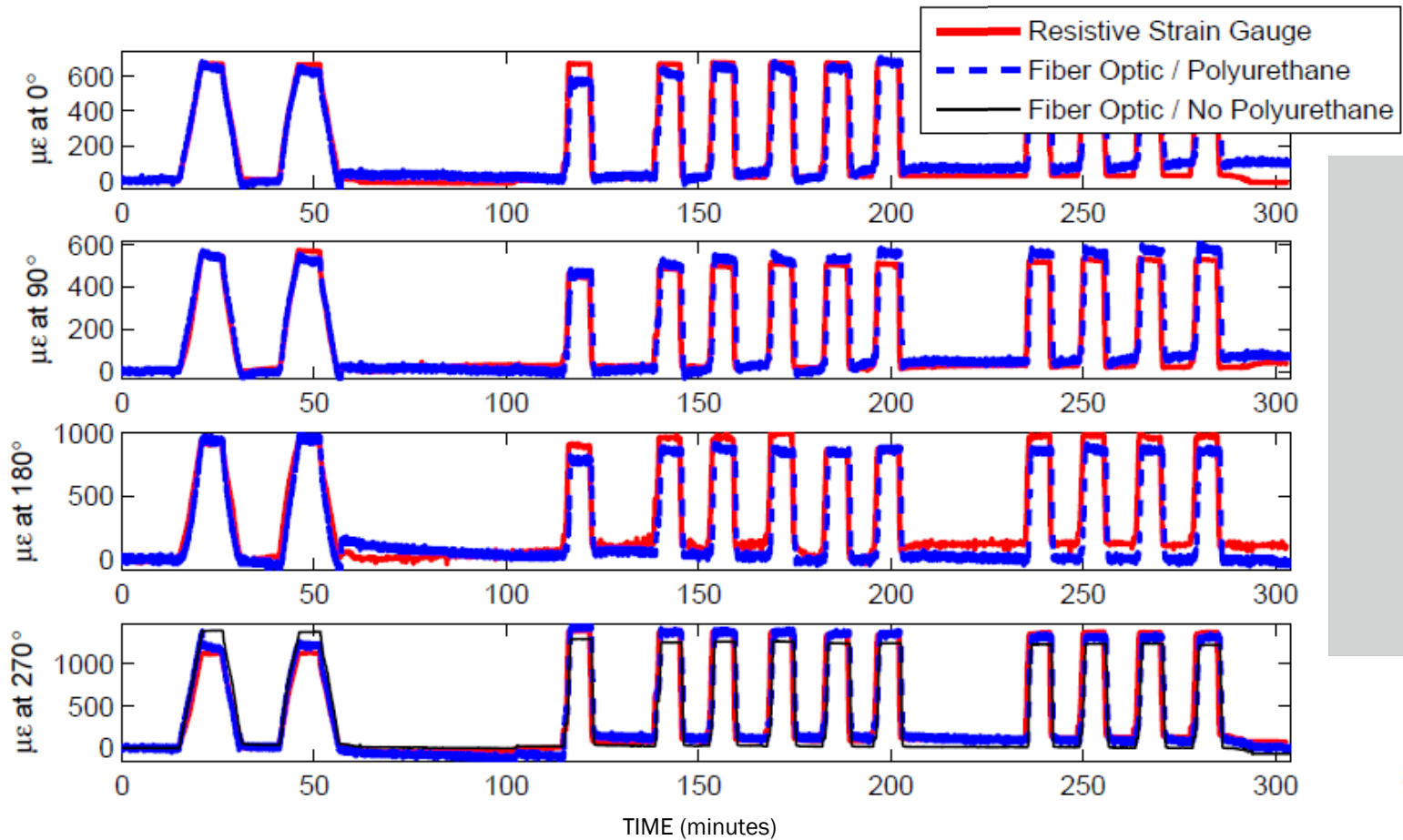


# UNIFORM LOADING IN COMPRESSION & TENSION

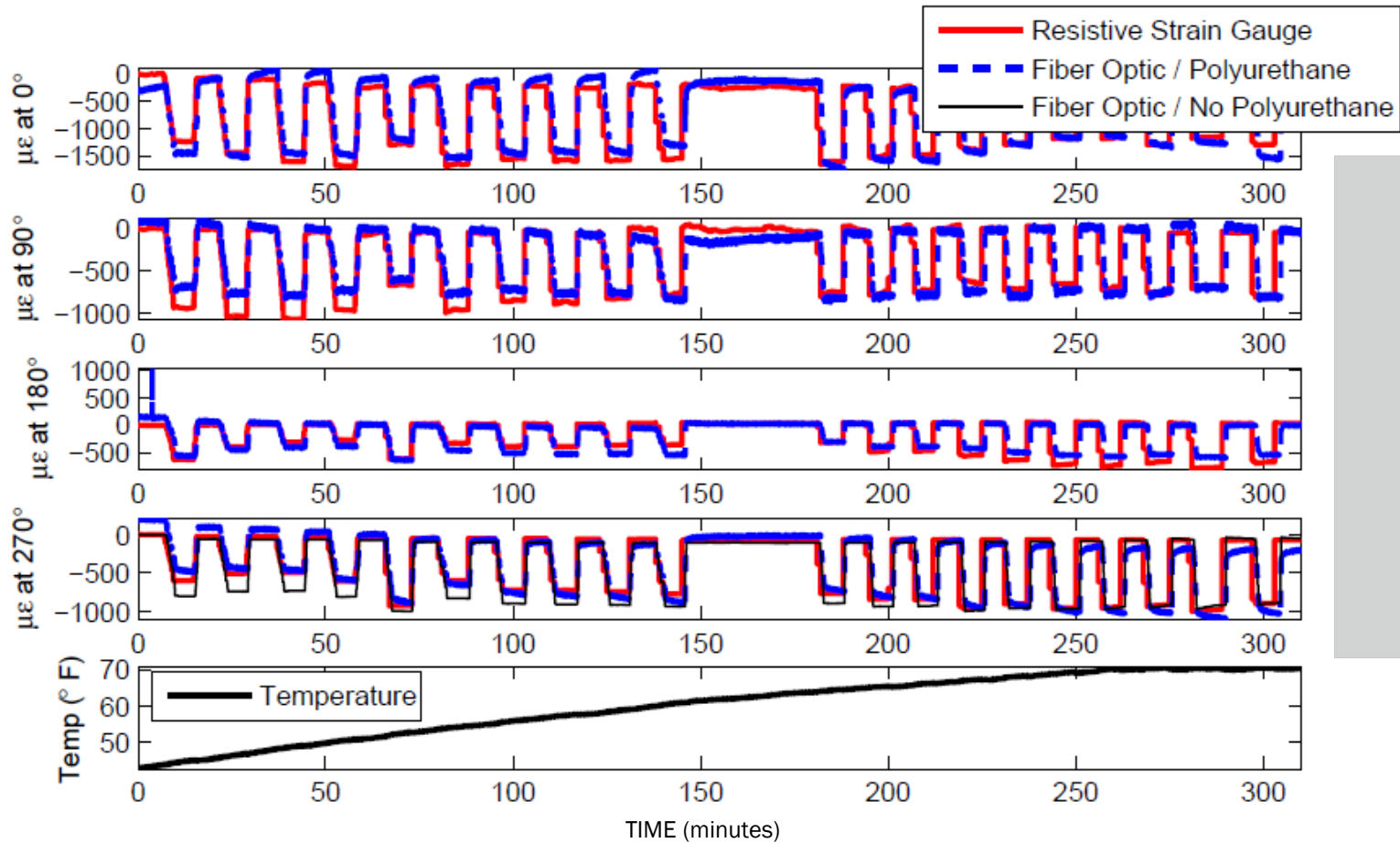




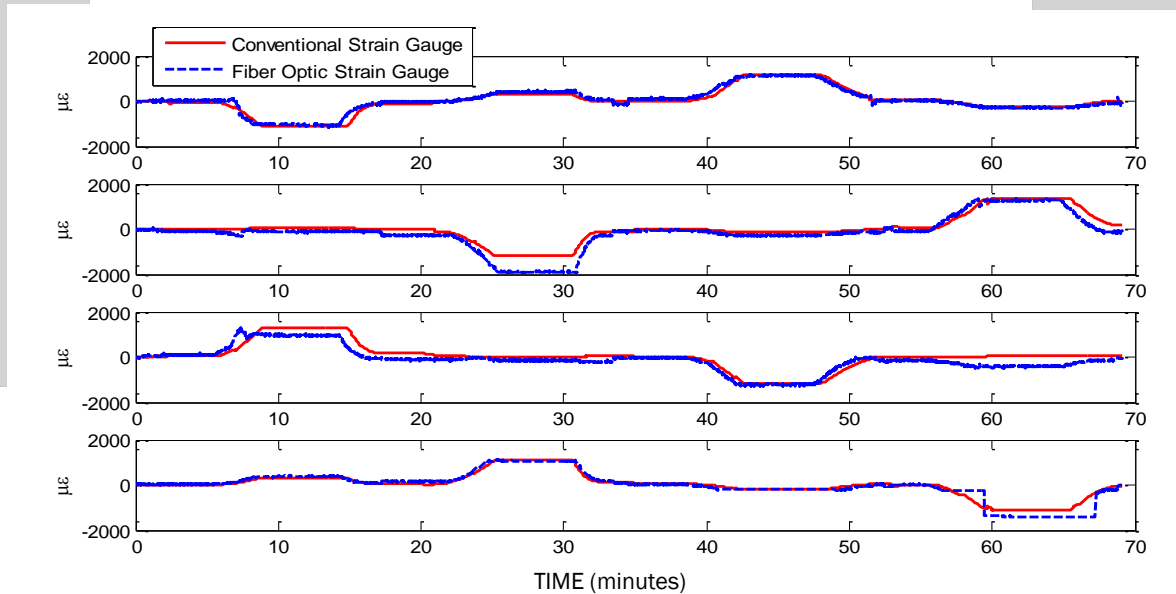
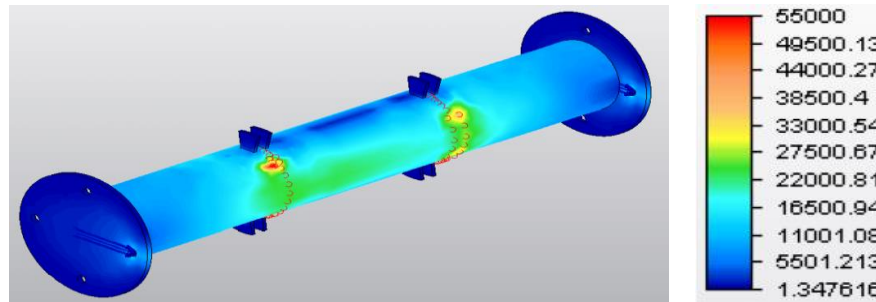
# TENSION COMPARED TO CONVENTIONAL STRAIN GAUGES



# COMPRESSION TESTING RESULTS



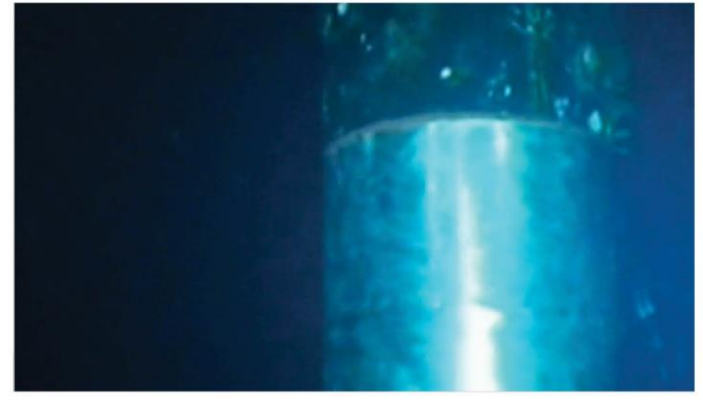
# UNIFORM LOADING IN 4-POINT BENDING



# TENDON BAND PREPARATION



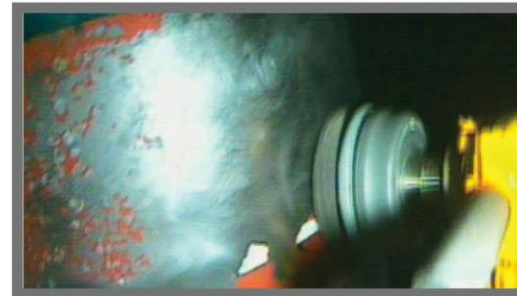
**Marine Growth**  
(BEFORE)



**Clean Band**  
(AFTER)



**Cleaning with Water Jet**



**Polishing to Bare Metal**

# DIVER INSTALLATION



Diver with Clamp



Riser Preparation

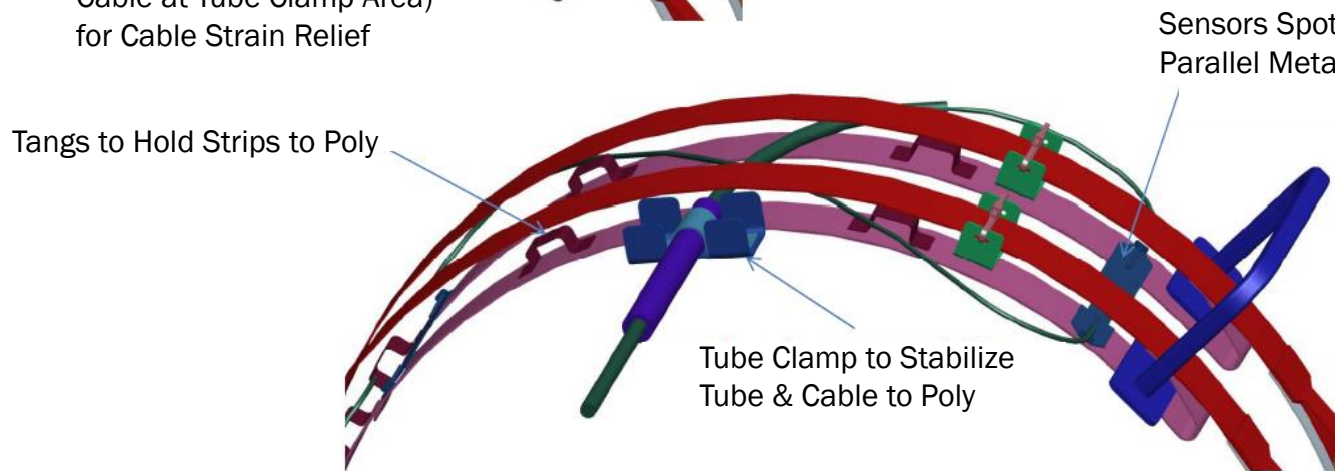
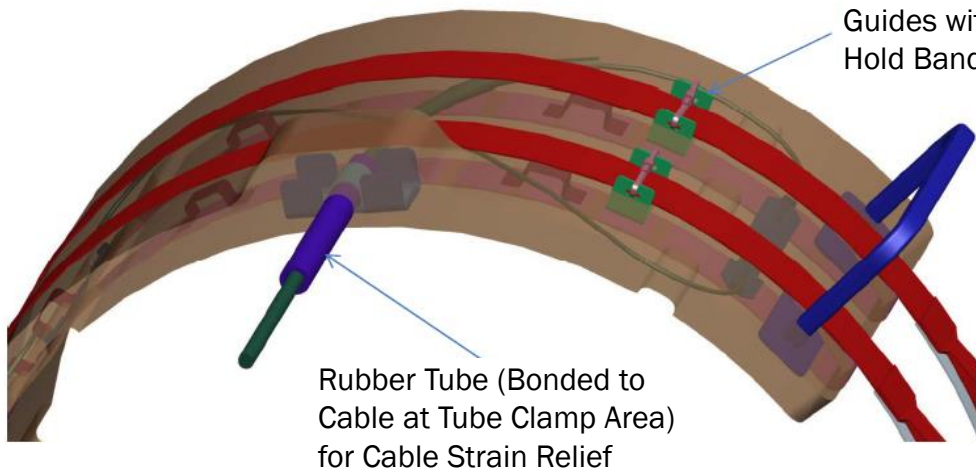


Clamp Installation

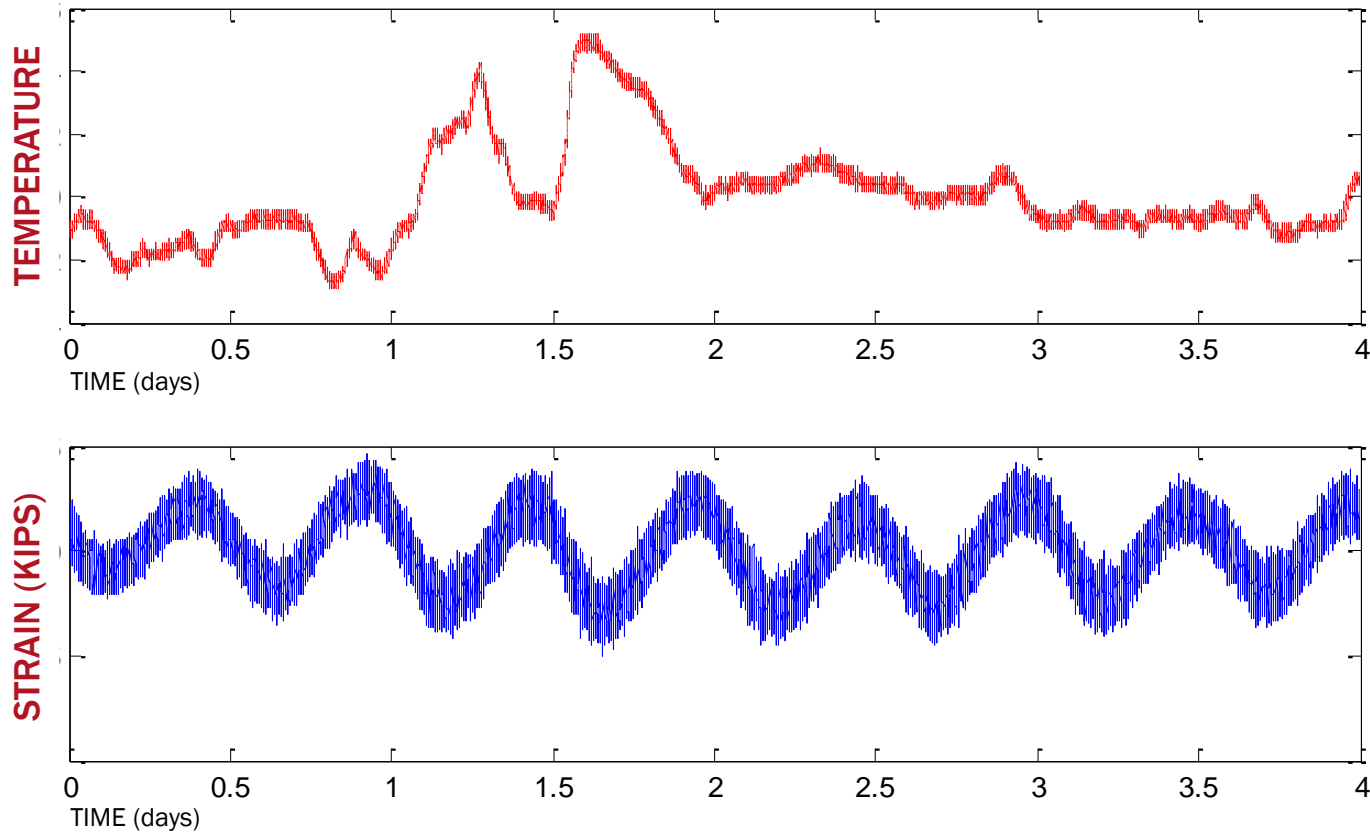


Clamp Inspection

# HARDENED SENSOR STATIONS

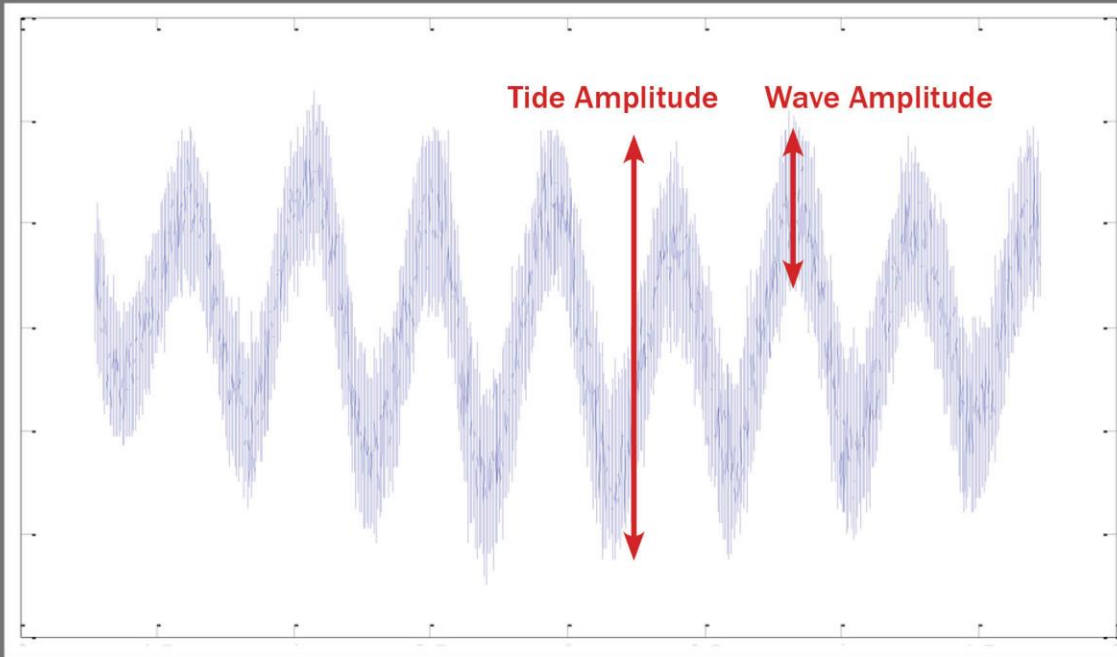


# TEMPERATURE & STRAIN GAUGES

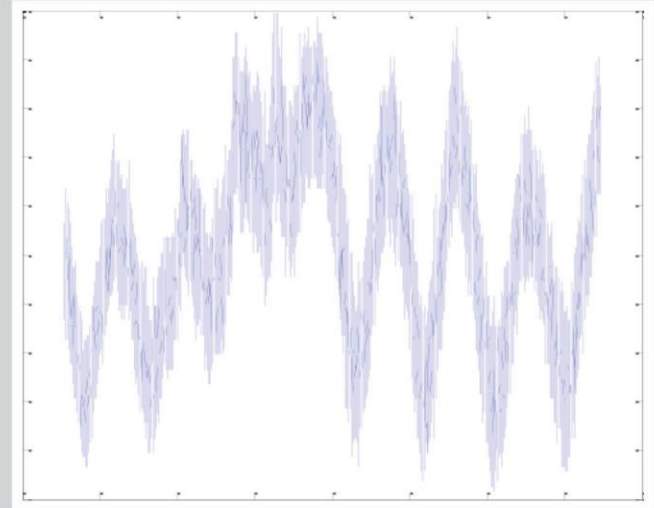


# OBSERVING TIDE CYCLES

WITH TEMPERATURE COMPENSATION

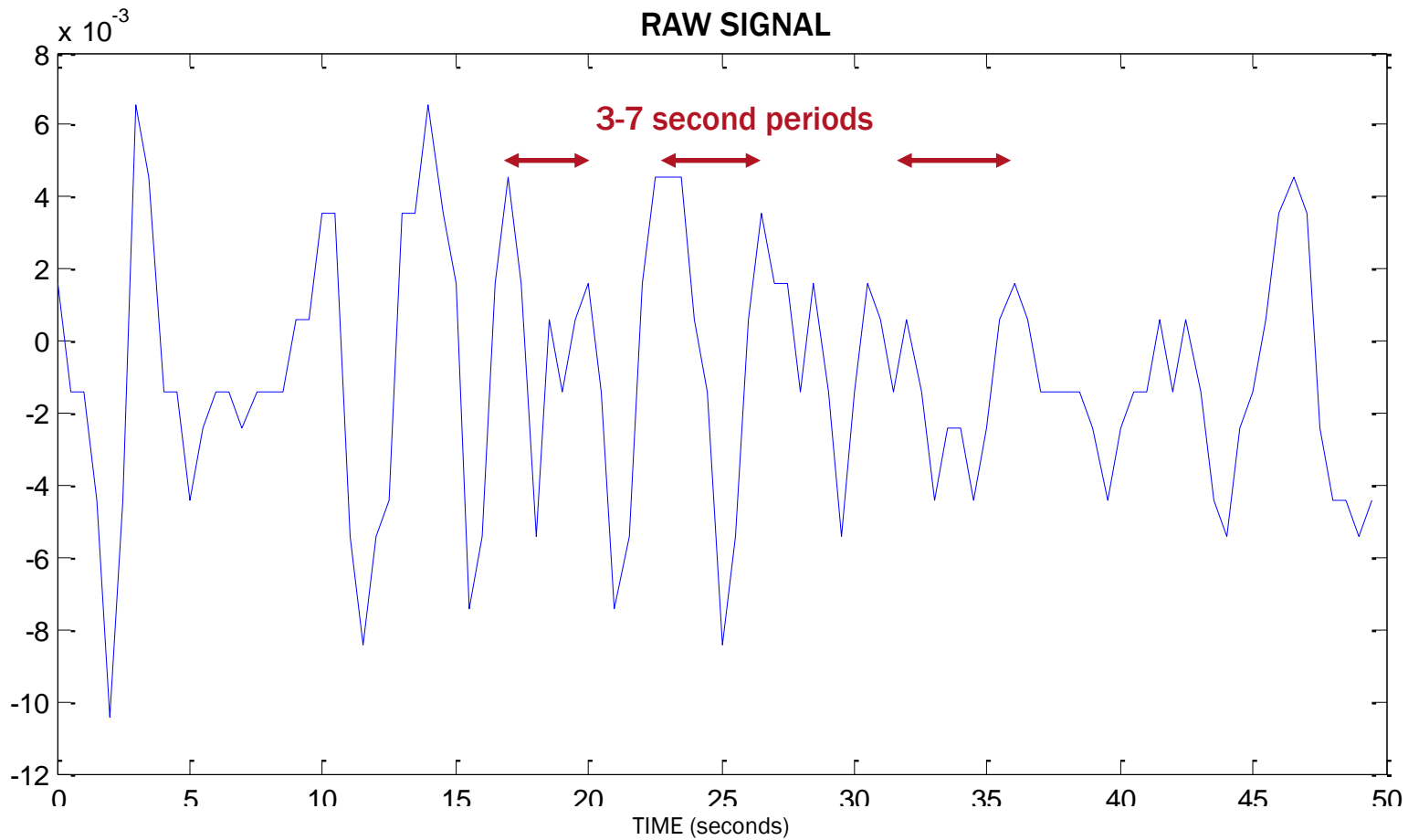


WITHOUT TEMPERATURE COMPENSATION

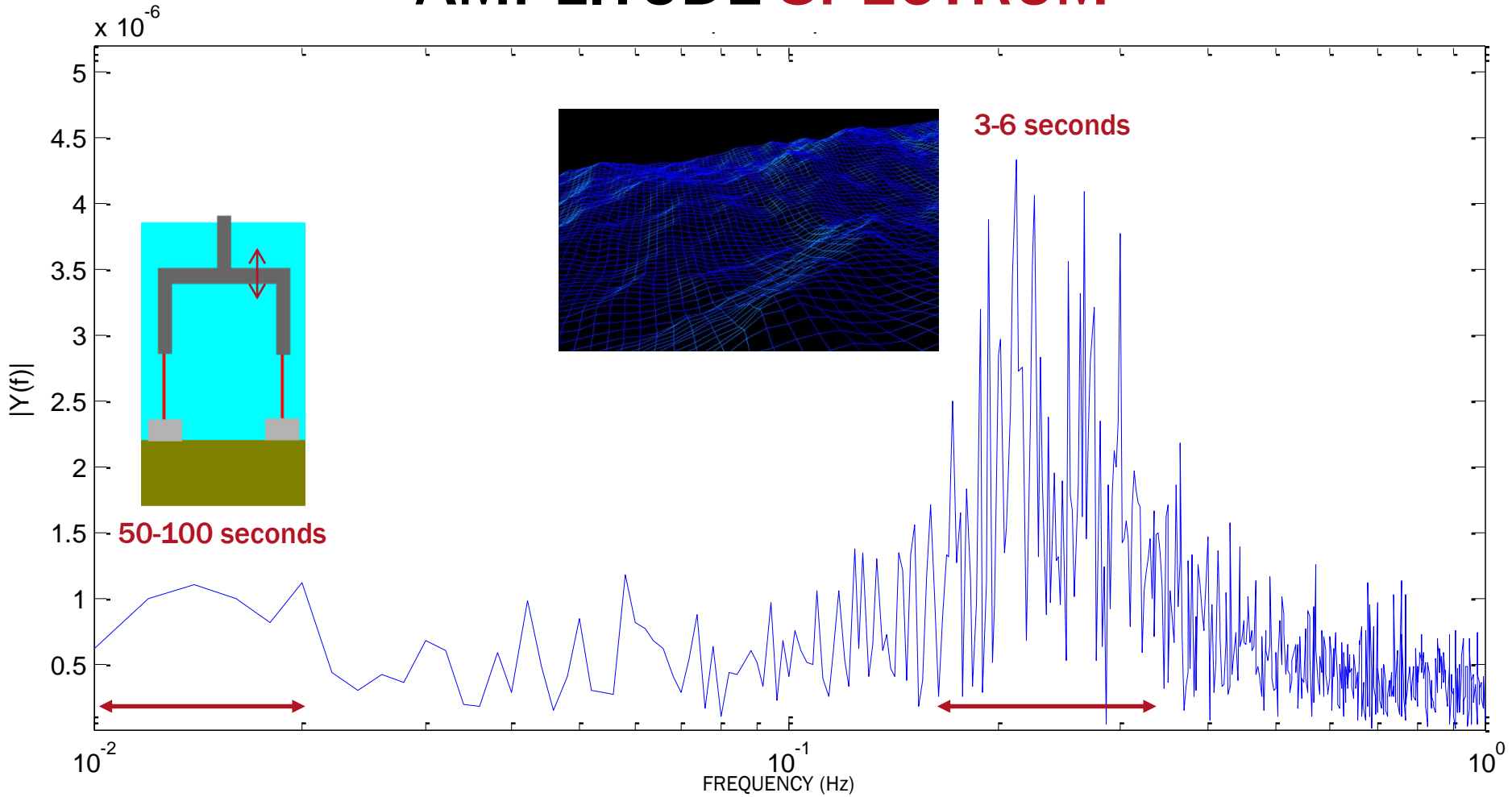




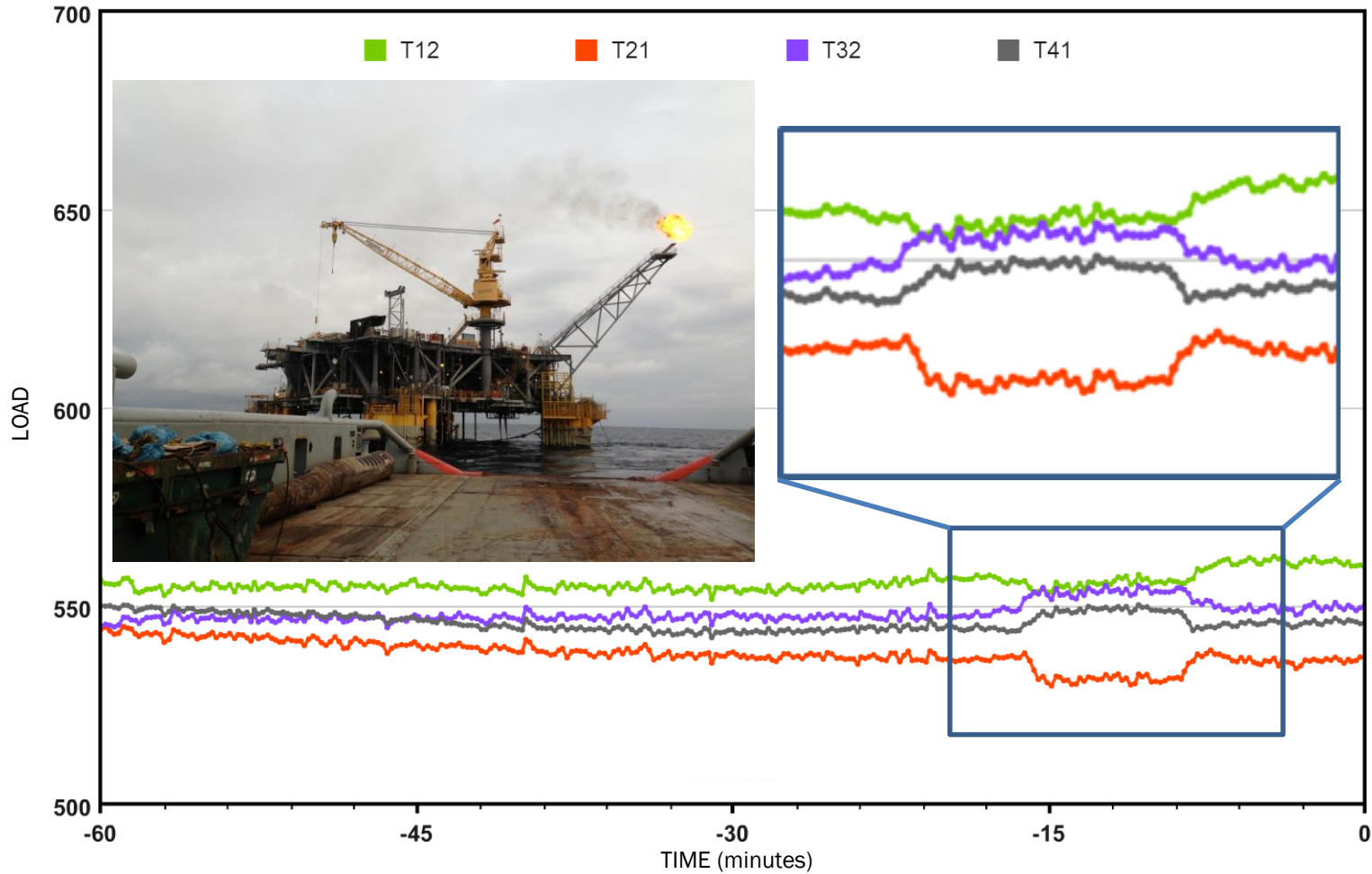
# OBSERVING WAVE ACTION



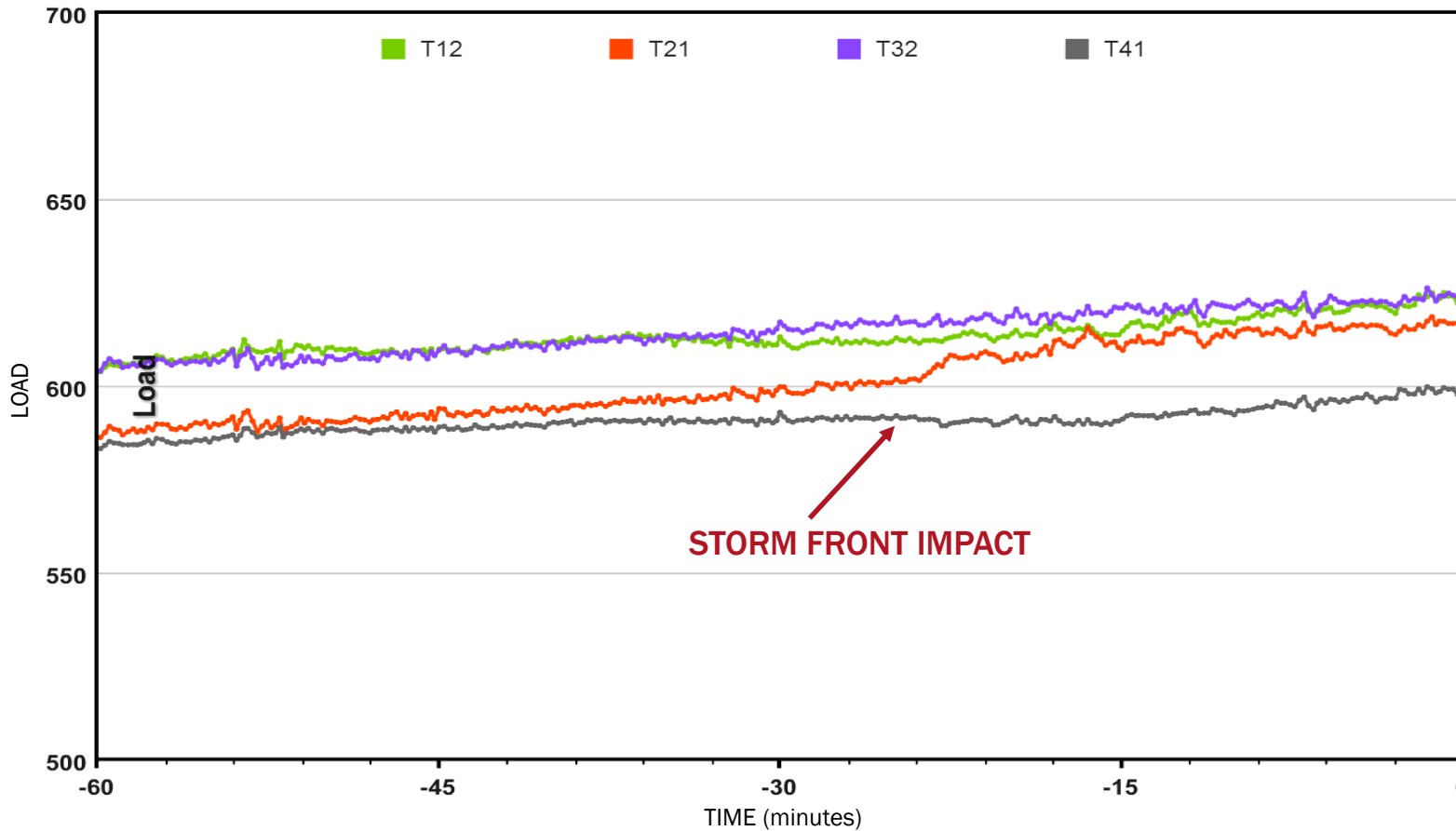
# AMPLITUDE SPECTRUM



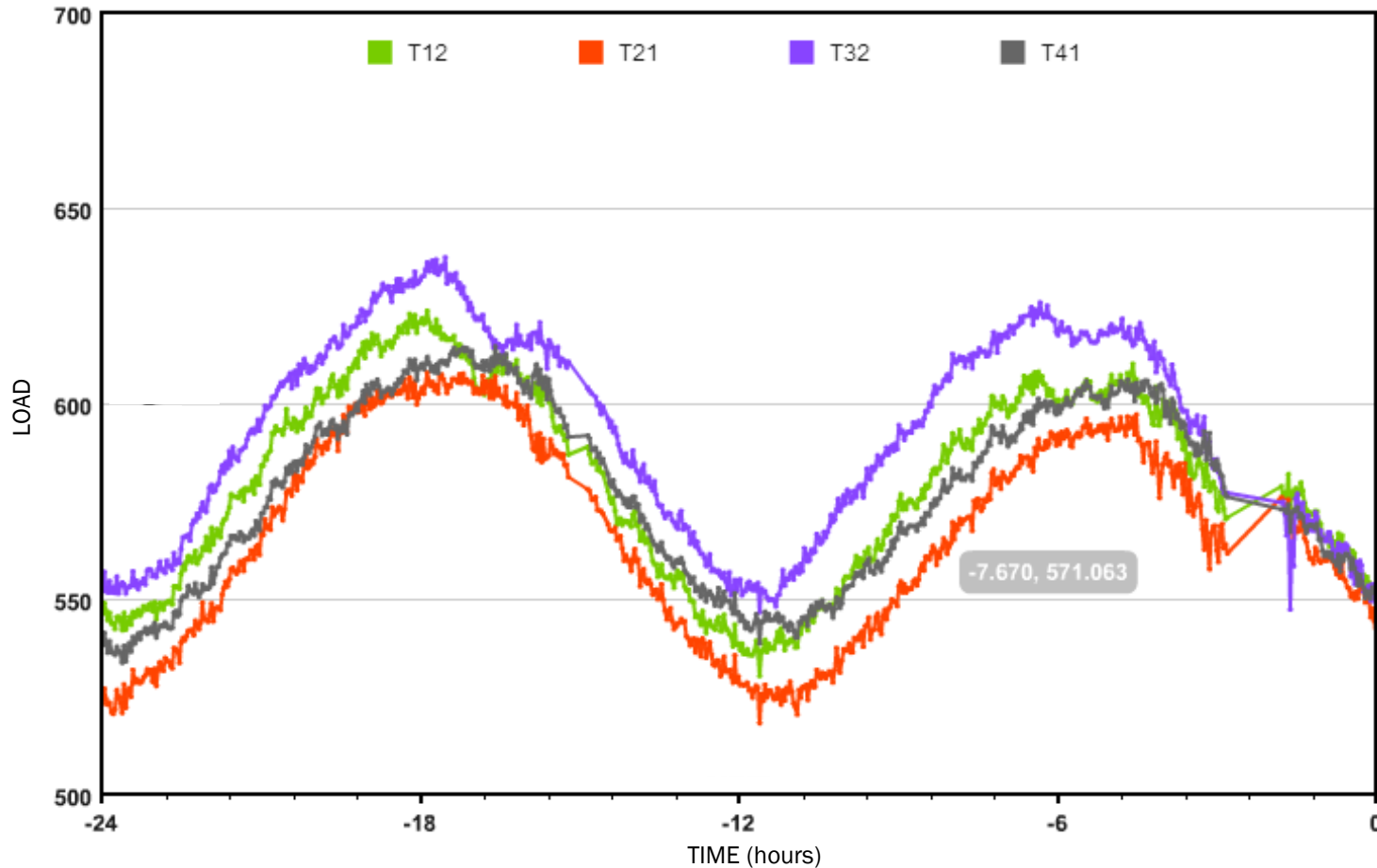
# BOAT DOCKING



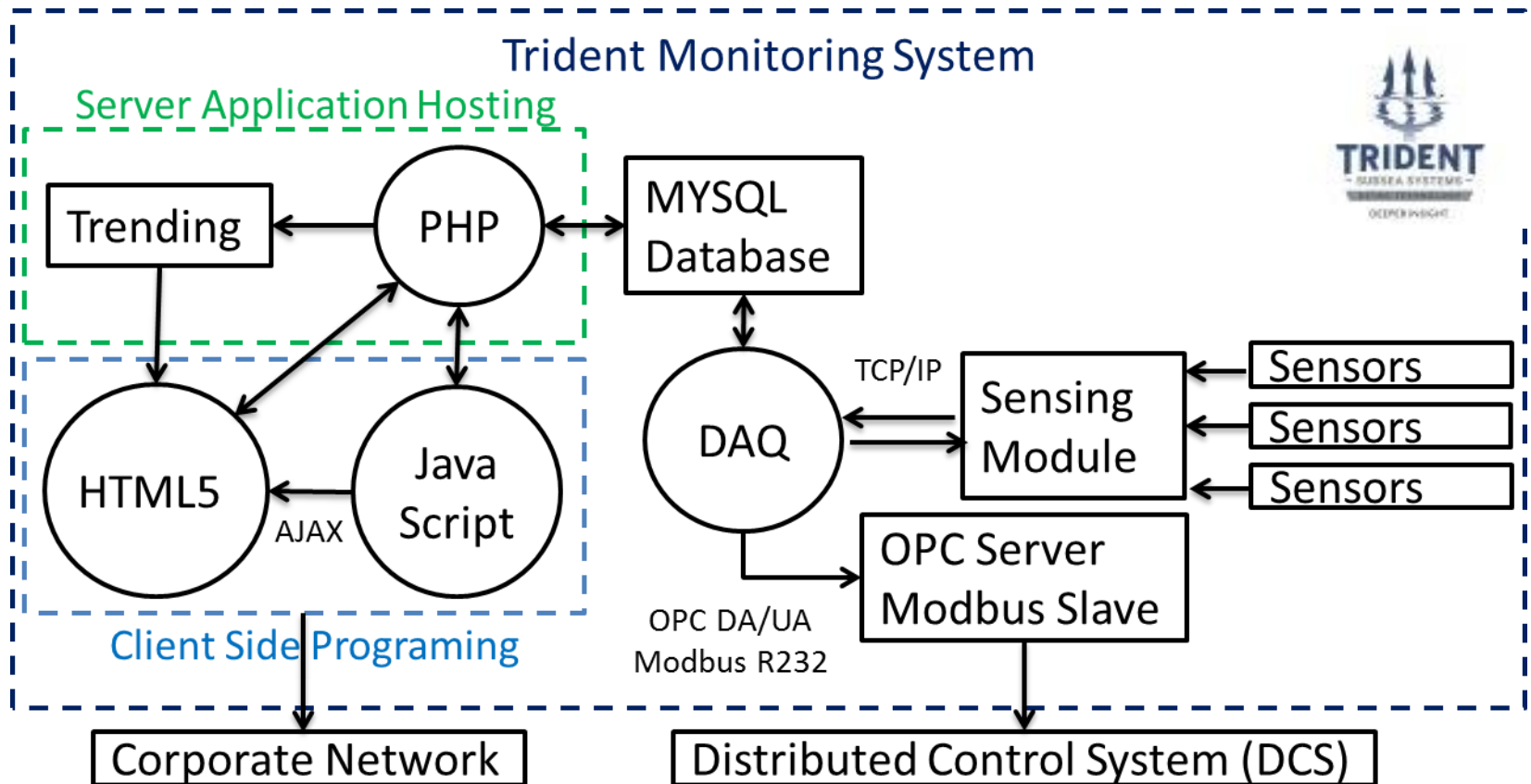
# WEST AFRICAN ENVIRONMENT: SUDDEN AND POTENTIALLY VIOLENT SQUALLS



# SENSOR CALIBRATION WITH TIDE CYCLES



# TRIDENT MONITORING SYSTEM



# ADVANCED DEEPWATER MONITORING **SUMMARY**

- Flow Lines (Temperature, Pressure, Hydrates)
- Risers, Tendons (Strain, Fatigue, Vibration)
- New Data Acquisition Overview
  - Calibration on Post-Installed Systems
  - Key Software Architecture Elements
- Observing Unique and Interesting Events
- Synthesizing Data into Actionable Information
  - Delivered to Key Decision Makers
- Future Activities Include Automation of Load Balancing and Abnormal Event Detection





# CLEAR GULF JOINT INDUSTRY PROJECT (JIP)

- Collaboration between oil and gas industry, NASA and Astro Technology

## PROPOSED PARTNERS INCLUDE:



- Create cutting-edge techniques for managing production
- Develop environmental and safety systems for drilling and production
- Respond to challenges faced when working in remote and harsh environments
- 7 specific deliverables for Phase-I on post-installed monitoring systems