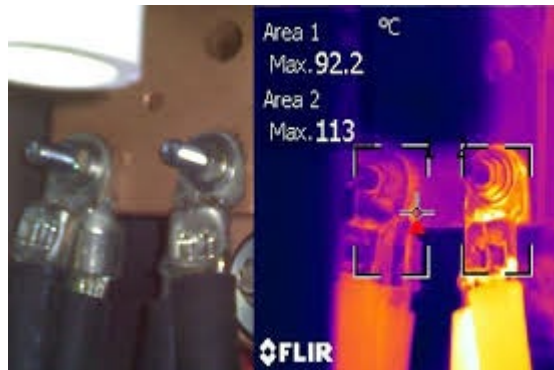


NSRP RA 2025-04: INSTALLATION OF A DISTRIBUTED TEMPERATURE SENSING SYSTEM FOR ELECTRICAL PLANT MONITORING

ELECTRICAL TECHNOLOGIES PANEL MEETING
May 5, 2026



Giovanni Tomasi
RSL Fiber Systems, LLC

Team Members:

- NAVSEA 05Z33
- NSWC PD
- NSWC DD
- Austal USA
- Leonardo DRS
- Penn State U ARL
- *AP Sensing*
- *ChemPro Technologies*
- *Visual Technologies, Inc.*

PTR: Vincent Mangino, Electric Boat
ATI PM: Nick Laney

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BACKGROUND - The Need for Distributed Sensing

Damage Control & Condition Based Maintenance

- 8 Arc faults average per year throughout the U.S. Navy fleet switchboards and load centers.¹
- Electrical fires cost \$6 billion over 12 years period.²
- Ford class carrier generates three (3) times the power of a Nimitz class.
- USS New Orleans Fire in August 2025 which lasted 12 hours and resulted in injuries to two sailors.
- USS Bonhomme Richard fire in 2020, which burned for five days and led to the total loss of the ship.
- USS Miami submarine fire in 2012, which caused over \$700 million in damage and resulted in the vessel's decommissioning.

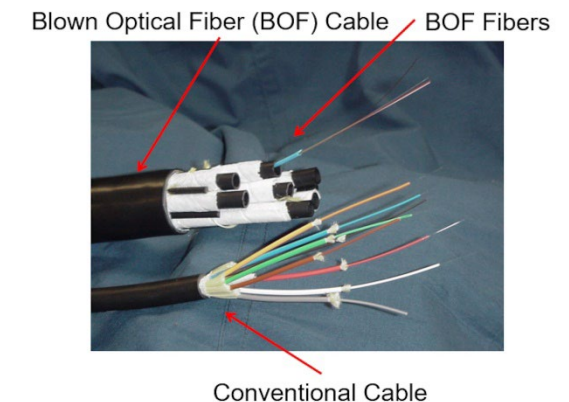
Traditional sensing mechanisms lack the coverage necessary to transition to an intelligent ship paradigm.



1. J. Callen, Penn State Electro-Optics Center, "Distributed Temperature Sensing for Inspection of Electrical Panels on Navy Ships", NSRP Meeting, March 2017.
2. Naval Sea Systems Command Office of Corporate Communications, "NAVSEA establishes new group to improve industrial fire safety", December 6, 2021.

Shipboard Fiber Optic Networks

- Approximately **1,220 Km (4 million ft)** of Optical Fiber on Ford Class Carrier¹
- New shipboard cable designs have upwards of **432 fibers**.
- These existing shipboard fiber optic infrastructures have the capacity for the creation of a shipboard “nervous system” through a network consisting of Distributed Fiber Optic Sensing (DFOS) technologies combined AI or ML discerning algorithm.²
- DFOS uses laser pulses to transform fiber optic cable into continuous, distributed sensors, providing a comprehensive sensing coverage utilizing preexisting fiber.



1. Huntington Ingalls Newsroom January 11, 2016
2. Joshua Carter, NSWCCD “Towards an Intelligent Shipboard Nervous System: Distributed Fiber Optic Sensing”, 24 October, 2022

CBM + DFOS + Digital Twin → A Paradigm Shift

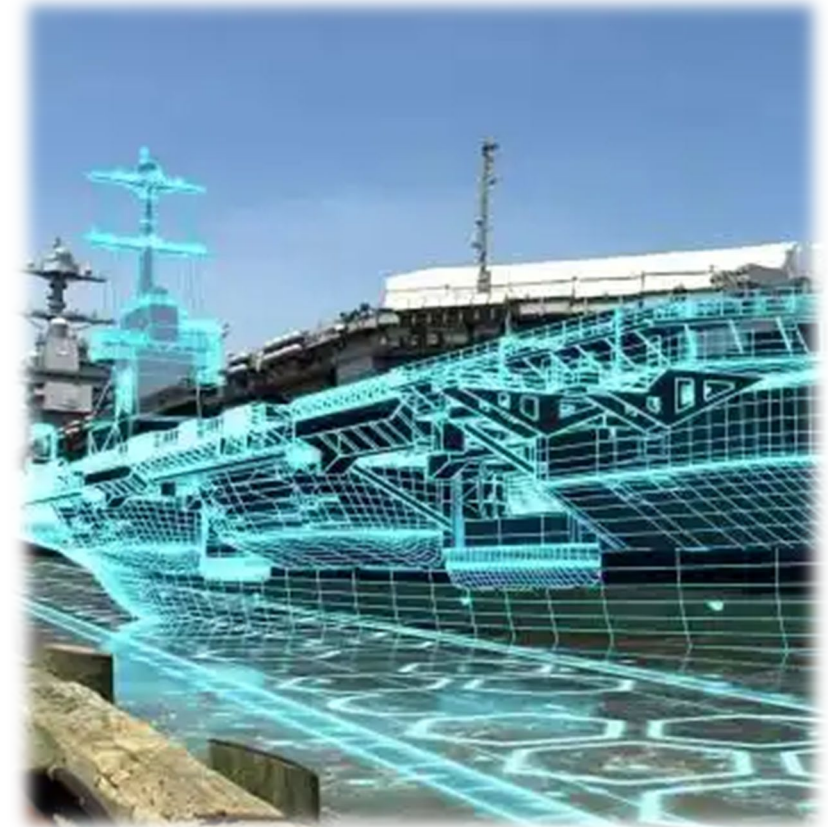
CBM+

- U.S. Navy is transitioning from a traditional, reactive maintenance model to a proactive, data-driven approach
→ **Condition-Based Maintenance Plus (CBM+).**
- Aim is to increase *operational availability and reduce costs*.
 - Operations & Support → 65% to 80% of Lifecycle Costs¹
 - U.S. Navy spent \$ 25.9 Billion in maintenance from FY 2020 to FY 2023.²
 - 73% of officers indicated spare parts shortages hinders maintenance.²

Digital Twin via Enterprise Remote Monitoring (eRM v4)

- **Digital Twin:** a computer model trained on historical HM&E system operational data, which can be deployed shipboard within eRM to predict nominally healthy performance and indicate when anomalies are occurring that need to be addressed.
- Leverages *operational data* and reports from embedded sensors to produce virtual replicas of physical assets. These digital twins provide a powerful simulation and analysis *tool for predicting equipment failures* long before they occur.
 - *Requires 3000-5000 sensors.*

1. DoD Condition-Based Maintenance Plus Guidebook, August 2024
2. <https://www.gao.gov/products/gao-25-106990>



ELECTRICAL SWITCHBOARDS

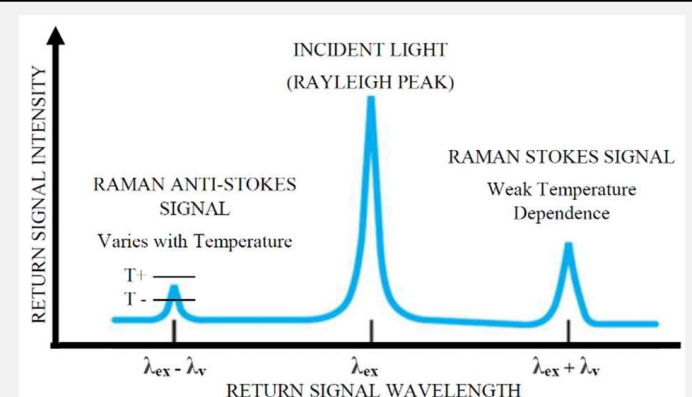
PROBLEM STATEMENT

1. **Potential of electrical system faults can not be predicted in real-time.**
 - Periodic open-door maintenance inspection of all connections are required every 6 to 12 months.
2. **Faults are expensive!**
 - Repairs + availability delays.
3. **Current inspection methods do not support CBM+**



SOLUTION – RAMAN DISTRIBUTED TEMPERATURE SENSING

- Mature technology:
 - Commercial: **TRL 9**
 - Navy: TRL 6 → After LBES Install: **TRL 7**
- Monitors temperature in **real-time** using entire length of the fiber.
- *Detect faults, isolate location, determine severity and define action.*
- Used extensively in commercial applications: **data centers**, fire detection, machinery, pipelines, oil exploration...



MIL-DTL-32772: 3.6.13 Non-contact thermal sensors. When specified (see 6.2), fiber optic temperature sensors or other technologies shall be provided to determine temperatures of selected current carrying joints or expected hot spots (see 4.4.3.8.7). ***Temperature sensors shall be permanently mounted***

NSRP PROJECTS HISTORY

Inspection of Electrical Assets

OBJECTIVES:

- Prevent damage due to loosened connections (arcing).
- Reduce risk to personnel.
- Reduce maintenance costs.
- **Perform Condition Based Maintenance (CBM).**



- **2015 – PSU EOC**, HII-Ingalls, SUPSHIP GC: Reduce risk of inspection of MV Electrical panels by use of windows for IR thermal imaging.
- **2015 – RSL Fiber Systems** presents fiber optic Raman DTS at NSRP Electrical Technologies Panel mtg (San Diego).
- **2017 – PSU EOC**, HII-Ingalls, SUPSHIP GC: Evaluation of DTS for monitoring MV electrical panels.
- **2019*** – **Hepburn & Sons**, RSL FS: Raman DTS to monitor connections of Insulated Bus Pipe (IBP).
- **2020*** – **Hepburn & Sons**, RSL FS: Raman DTS to monitor IBP connections to equipment.
- **2023 – RSL Fiber Systems**, NAVSEA 05Z33, NSWC PD, BIW, PSU EOC: DTS Integration into Electrical Plant Controls.
- **2025*** - **RSL Fiber Systems**, NAVSEA 05Z33, NSWC PD, NSWC DD, Austal, Leonardo DRS, PSU EOC, AP Sensing: DTS Installation on DDG 51 Land site.



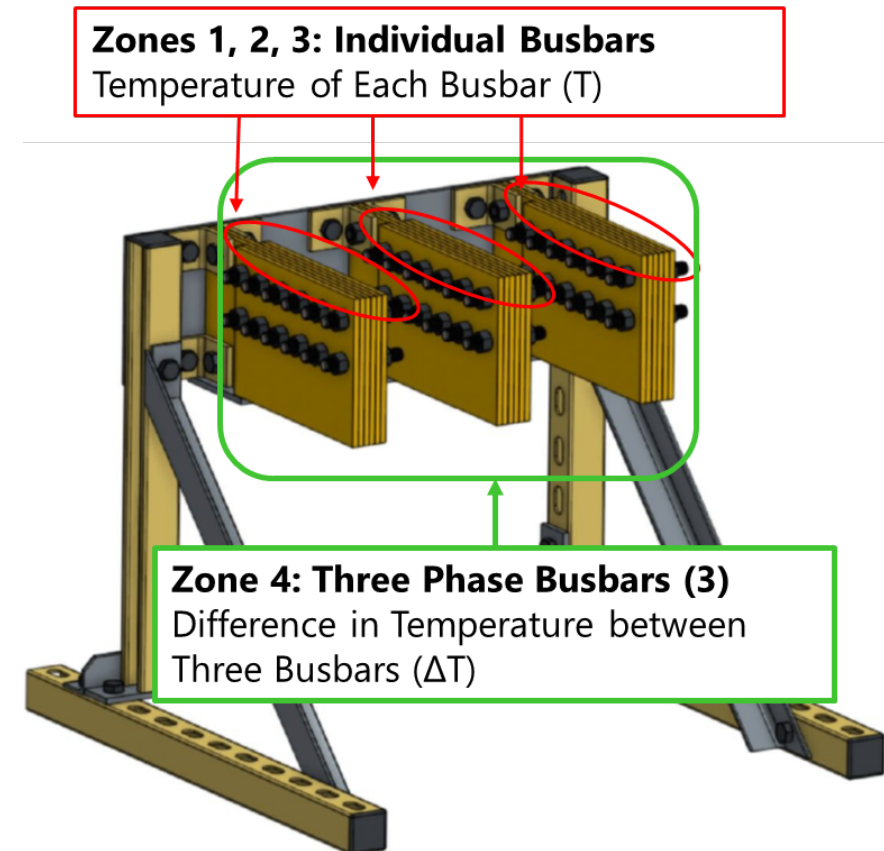
* NSRP Research Announcements

NSRP RA 2025-04 METHODOLOGY

Monitor the temperature of busbars in real time to detect abnormal temperatures at the individual busbar and differences in temperature between the three (3) phases.

| Priority | Temp Rise or ΔT | Operational Assessment | Severity Code | Action |
|----------|--|------------------------|---------------|--|
| 1 | $\geq 70^{\circ}\text{C}$ | Failure Imminent | **** | Equipment should be secured immediately and not operated until repairs are complete. |
| 2 | 40°C to $< 70^{\circ}\text{C}$ | Failure Almost Certain | *** | Equipment should be secured if operating conditions permit otherwise monitored until corrective action can be taken. |
| 3 | 20°C to $< 40^{\circ}\text{C}$ | Failure Possible | ** | Corrective action should be taken as soon as feasible. |
| 4 | 10°C to $< 20^{\circ}\text{C}$ | Performance Degraded | * | Corrective action should be taken at next scheduled routine maintenance period or as schedule permits. |
| | $< 10^{\circ}\text{C}$ | N/A | N/A | No corrective action required; note for future reference. |

Table 7.1 from NAVFAC P-604 E-SAFE (2019)



NSRP RA 2025-04 OUTLINE

OBJECTIVE: configure, install, and operate a DTS system at a Navy land facility for hands-on experience and to identify modification(s) required for installation on an in-service vessel through a Ship Change Document (SCD) for a Temp Alteration.

- Eliminate arc faults.
- Perform CBM before damage occurs.

TASKS

Task 1 – Configure the Sensing Assemblies.

Task 2 – Configure the DTS Interrogator Hardware.

Task 3 – Configure the Monitoring Software and Graphical User Interface.

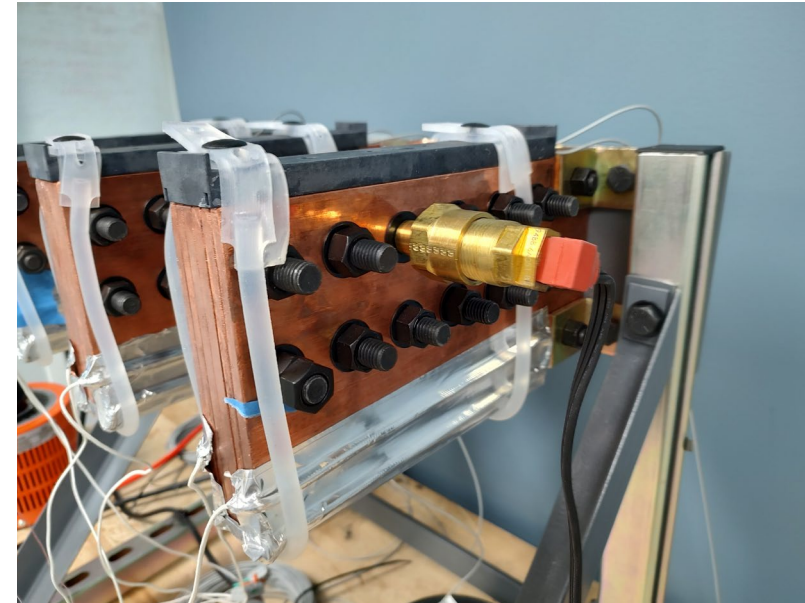
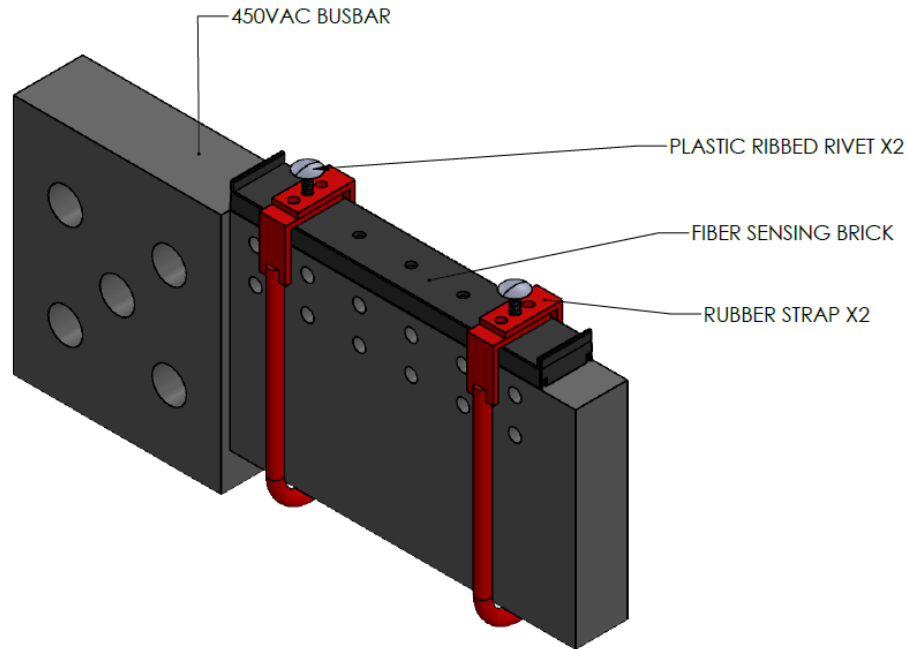
Task 4 - Installation at the DDG 51 Land Based Engineering Site (LBES) in Philadelphia.

DELIVERABLES

- DTS System Configuration
- Assembly Design
- GUI Design
- DTS System Installation, Operation, and Verification Plans and Implementation
- Tech Transfer Plan



TASK 1 - ASSEMBLY DESIGN



- Sensing Bricks to MIL-M-24519 (Materials used in Electric and Electronic Equipment).
 - Attachment to Busbar to meet MIL-STD-901D Shock and MIL-STD-810 Vibration.
-
- Built assembly prototypes and confirmed fitting on Tactical LV Switchboards at LBES.
 - Developed test method to determine heat transfer from loosening bolt(s) to sensing fiber.

TASK 1 - ASSEMBLY DESIGN

OBJECTIVE – Prevent fiber cable from **arcing** across busbars.

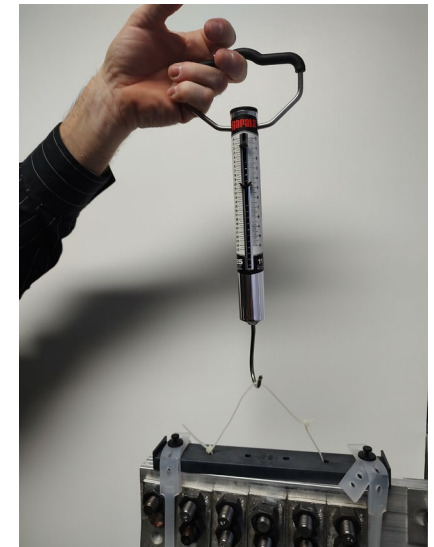
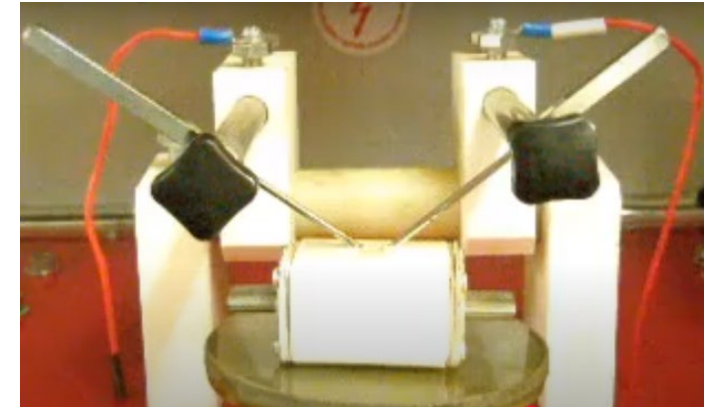
- Tested M85045/16 cable jacket to ASTM D 495 – Dry Arc Resistance of Solid Electrical Insulation.
- **Passed** requirements for use in LV and MV switchboards.

OBJECTIVE – Sensing bricks to pass **Shock & Vibration**.

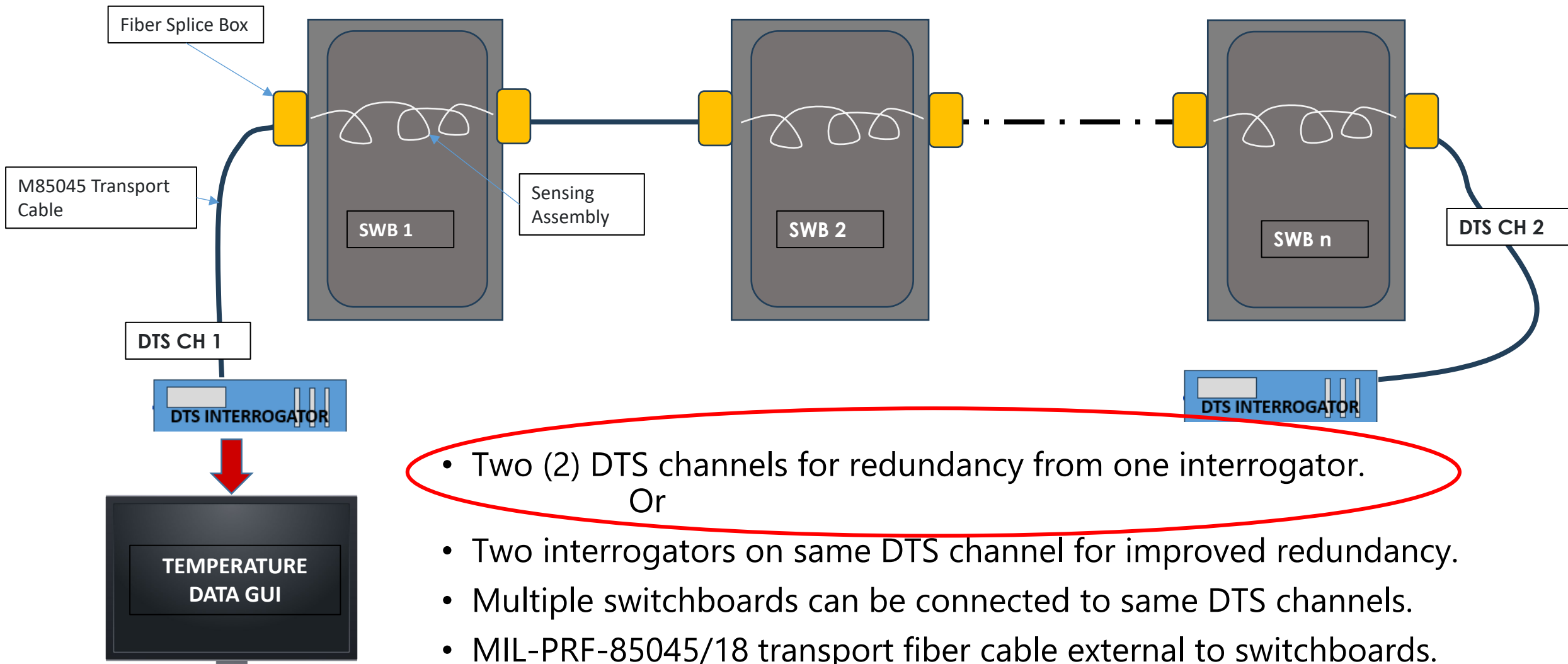
- Straps of silicone to MIL-A-46146, (-45 to 200°C).
- 7 – 9 lbf of downward force. ≥ 65 G required to cause minimal movement of sensing brick.
- Run Shock & Vibration at AeroNav before on-ship install.

OBJECTIVE – Prevent cable **jacket melting** during operation.

- MIL-DTL-32772 3.3.6 Insulating Materials for Bus Supports and Spacers: Class B per MIL-DTL-917 266°F (130°C).
- Lab Tested 4 hrs. hot plate @130 – 133°C. **No** jacket & sensing bricks melt, flow, or deformation.

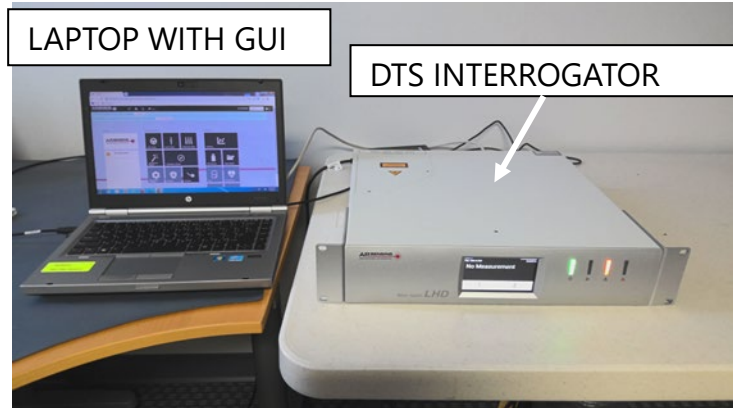


TASK 2 – DTS SYSTEM CONFIGURATION

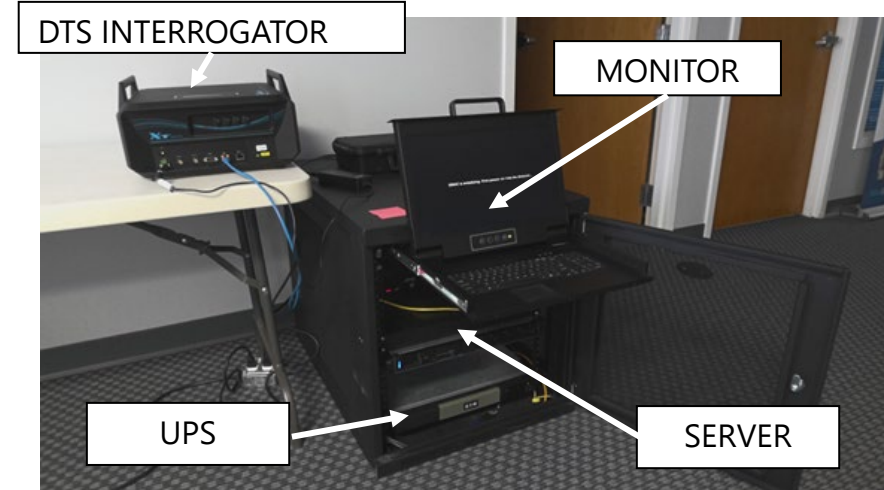


- Two (2) DTS channels for redundancy from one interrogator.
Or
- Two interrogators on same DTS channel for improved redundancy.
- Multiple switchboards can be connected to same DTS channels.
- MIL-PRF-85045/18 transport fiber cable external to switchboards.
- M85045 cable spliced to internal fiber optic sensing cable assembly.

TASK 2 – DTS SYSTEM – HARDWARE SELECTION



AP SENSING DTS SYSTEM TESTED



SILIXA DTS SYSTEM TESTED

| Item | Manufacturer | AP SENSING | Silixa |
|------|--|------------|--------------|
| 1 | Model No. | N4585A | Ultima M |
| 2 | Max. Meas. Range | 2, 4, 8 Km | 10 Km |
| 3 | No. Channels | 4 | 4 |
| 4 | Meas. Accuracy (°C) | < 0.1°C | 0.01°C |
| 5 | Length of fiber required for sensing (minimum definable zone length) | 2 m | >1 m |
| 6 | Sensing Zones x Channel | 2,000 | Up to 40,000 |
| 7 | Sampling Interval | 0.25 m | 0.25 m |

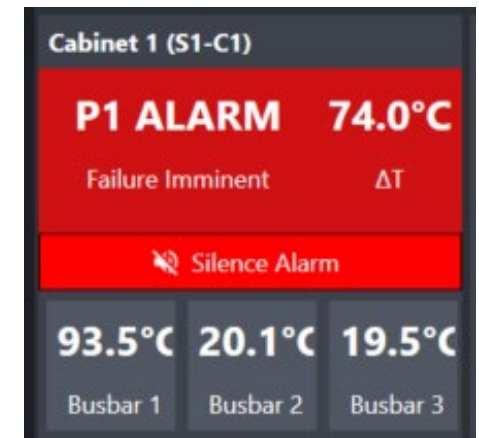
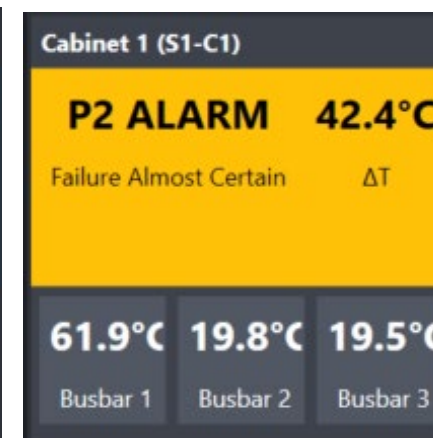
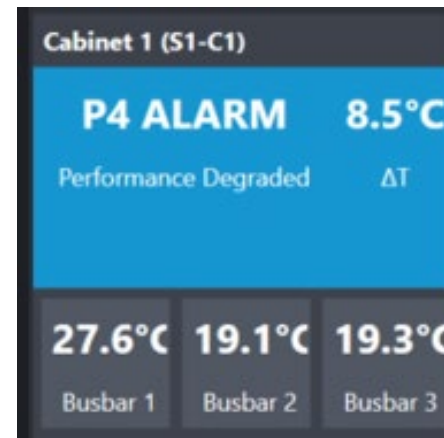
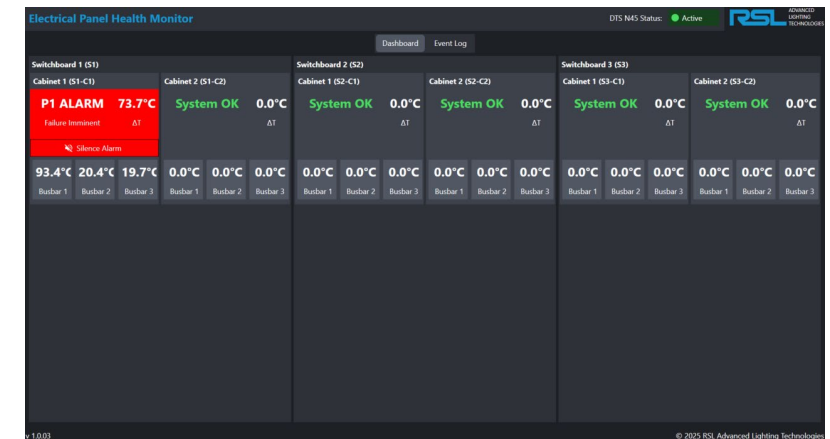
| Manufacturer | SILIXA | | AP SENSING N4585A-xxx | | |
|-----------------------------------|-----------|-----------|-----------------------|----------|----------|
| Model No. | Ultima M | XT-DTS M | -R02 | -R04 | -R08 |
| Measurement Range (meters) | 10,000 | 10,000 | 2,000 | 4,000 | 8,000 |
| | Cost Ea. | | Cost Ea. | | |
| Interrogator | \$70,205 | \$72,437 | \$24,659 | \$28,182 | \$34,171 |
| 4 Sensors Channel | | | \$5,474 | \$5,474 | \$5,474 |
| Integrated Interface | | | \$577 | \$577 | \$577 |
| Server | \$4,800 | \$4,800 | | | |
| Software License | \$47,187 | \$47,187 | | | |
| Rack Housing w/integrated display | | | \$166 | \$166 | \$166 |
| | \$122,192 | \$124,424 | \$30,876 | \$34,400 | \$40,388 |

TASK 3 – CONFIGURE SOFTWARE AND GUI

- AP Sensing SmartVision suited for large area systems (Pipelines, Powerplants, Power Grids...)
- Not able to compare different sensing zones.
- Visual Technologies, Inc. contracted to develop software and GUI.
- Modbus Communication protocol.

GUI MIL-STDs

- MIL-STD-1472H "Department of Defense Design Criteria Standard Human Engineering"
- MIL-DTL-32483 "Detail Specification: Switchgear, Power, Hard-Mounted, Medium Voltage, Naval Shipboard"



TASK 4 – INSTALLATION AND IMPLEMENTATION

- **Installation**
 - Up to two (2) days to install, set-up, and commission equipment.
- **Operation**
 - **No interference** with other functions/tests.
- **Maintenance / Repairs**
 - No maintenance required / anticipated for duration of project.
- Leave in place or remove at end of project (~ 1/2 day required for removal)



TASK 4 SUPPORT – Twin DTS System



- Busbars Mock-up built for RSL Fiber Systems lab.
- 2nd AP Sensing DTS System purchased by RSL.
- Modify GUI & Software based on LBES Team feedback.
- Evaluate and model heat transfer from bolted connection to sensing fibers.

NEXT STEPS

1. Schedule installation at the Philadelphia LBES [**May 2026**]
2. Operation at the LBES [**May - June 2026**]

| | | | 3 MONTH EXTENSION | | |
|------|---|--------|-------------------|--------|--------|
| | ACTIVITY | STATUS | 26-Apr | 26-May | 26-Jun |
| 1.0 | Configure the software and preliminary GUI | ✓ | | | |
| 2.0 | Build prototype assemblies | ✓ | | | |
| 3.0 | Meeting at LBES to fit assemblies | ✓ | | | |
| 4.0 | Perform ASTM D 495 on jacket materials | ✓ | | | |
| 5.0 | Finalize and build assemblies | ✓ | | | |
| 6.0 | Configure twin DTS system in RSL lab | ✓ | | | |
| 7.0 | Installation Plan | ✓ | | | |
| 8.0 | DTS Verification and Operation Plan | 80% | 100% | | |
| 9.0 | Installation in DDG 51 LBES LV Switchboards | | | | |
| 10.0 | Operation in LBES | | | | |

TECHNOLOGY TRANSFER

- Presentation at Machinery Failure Prevention Technologies 2025 Conference, May 2025, Virginia Beach, VA (G. Tomasi & C. Nemarich)
- Presentation at ASNE Fleet Maintenance & Modernization Symposium 2025, September 2025, San Diego, CA (G. Tomasi, J. Carter, C. Nemarich)
- RA 2026-02 Installation on In-Service Vessel (EPF Fast Transport Vessel)
- To be proposed 2027 RA (or ManTech): DTS for fire detection.

MFPT ANNUAL CONFERENCE

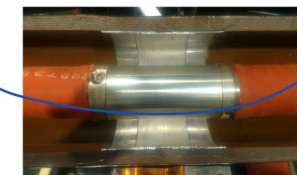
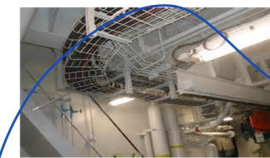
Diagnostics, Prognostics, and Failure Prevention
Where Theory Meets Practice

Network, exchange knowledge, and collaborate with professionals interested in machinery failure prevention technology.



AMERICAN SOCIETY OF NAVAL ENGINEERS

DTS – SHIPBOARD APPLICATIONS



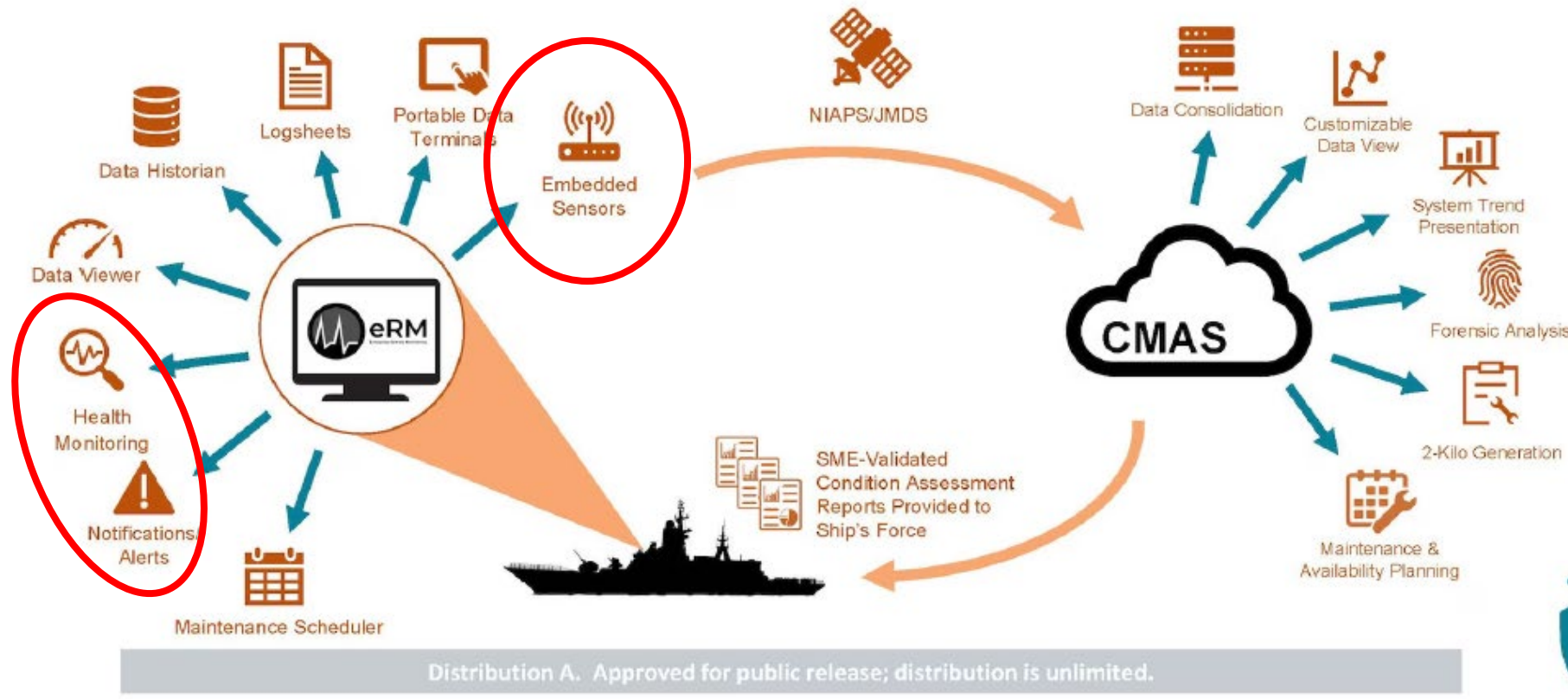
Data Displayed

- LV, MV, and HV electrical panels monitoring
- Insulated Bus Pipe Connections
- **FIRE DETECTION**
- Machinery health monitoring
- Cabling systems health monitoring
- Food storage spaces
- Others...
- **Single DTS and single cable for multiple functions**





CBM+ES Ecosystem



NAVSEA NEWS | Nov. 16, 2023

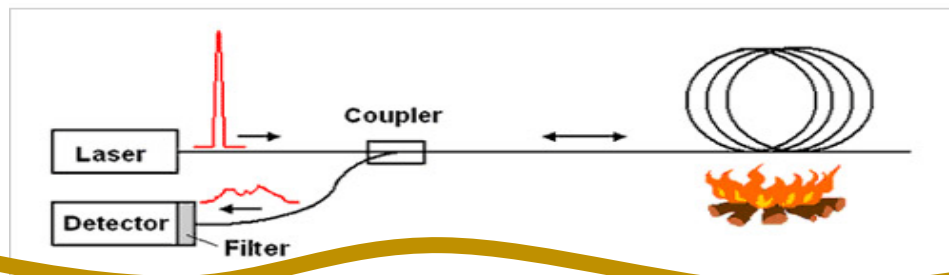
www.navsea.navy.mil/Media/News/Article-View/Article/3590550/nswcpd-engineers-spearheading-condition-based-maintenance-cbm-program-for-us-na/

QUESTIONS?

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FIBER OPTIC DISTRIBUTED TEMPERATURE SENSING

DTS INTERROGATOR



- Based on Raman Scattering.
- Entire fiber is the sensing unit – up to 10,000 programmable zones per fiber channel.
- Zones can overlap and encompass multiple zones.
- Multiple warnings / alarms can be set in each zone.
- Standard MM 50/125, 62.5/125 or SM fiber.
- Up to 30 Km MM, 40 Km SM - real time monitoring across entire length.
- Temperature rise of 0.1°C
- Spatial Resolution down to 50 cm.

