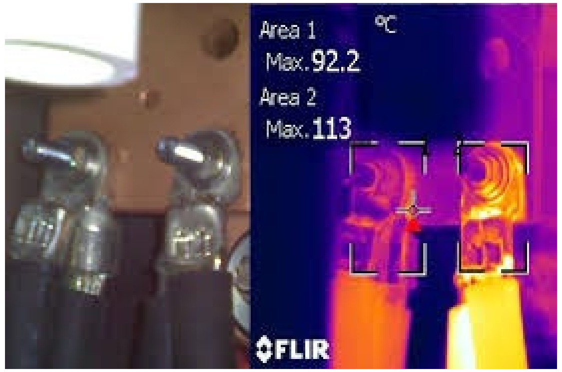
NSRP | National Shipbuilding Research Program

ADVANCED LIGHTING TECHNOLOGIES

NSRP RA 2025-04 & 2026-02:
INSTALLATION OF A DISTRIBUTED TEMPERATURE SENSING SYSTEM FOR ELECTRICAL PLANT MONITORING

Electrical Technologies Panel Meeting
Pullman, WA

August 18, 2026



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- NAVSEA 05Z33
- NSWC PD
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NATIONAL SHIPBUILDING RESEARCH PROGRAM™
Taking Shipbuilding and Repair to the Next Level

TABLE OF CONTENTS

- **BACKGROUND – DISTRIBUTED SENSING**
- **PROBLEM STATEMENT & SOLUTION**
- **PROJECT HISTORY**
- **NSRP RA 2025-04 OUTCOME**
- **NSRP RA 2026-02 OUTLINE**
- **TECHNOLOGY TRANSFER**

PROBLEM

ADVANCED LIGHTING TECHNOLOGIES

US Navy Faces Fires and Electrical Failures on Warships

A recently published article has detailed a troubling series of non-combat incidents affecting the United States Navy's advanced warships. According to a Chinese military magazine, Naval & Merchant Ships, these issues include significant electrical failures, propulsion problems, and fires aboard key vessels such as the USS Gerald R. Ford aircraft carrier and the USS Zumwalt destroyer. The report claims that these operational shortcomings have raised concerns about the fleet's overall effectiveness and readiness.

This troubling assessment highlights not only the immediate dangers posed by such technical issues but also suggests deeper, systemic vulnerabilities within the US Navy's modernization efforts. The report asserts that the frequency of these incidents indicates an erosion of naval capabilities, critical in a time when naval power is key to maintaining global security balance. High-profile vessels like the USS Dwight D. Eisenhower are also mentioned, underscoring that this is not an isolated issue but part of a broader pattern.

Army Index Global Tactical Analysis Center, July 7, 2026
https://armyindex.com/news/us-navy-faces-fires-and-electrical-failures-on-warships
[Source: South China Morning Post]

BACKGROUND - The Need for Distributed Sensing

Damage Control & Condition Based Maintenance

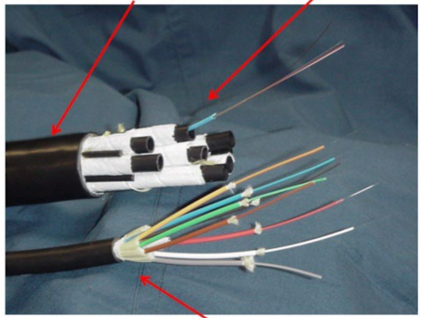
- *8 Arc faults average per year throughout the U.S. Navy fleet switchboards and load centers.[1]*
- Shipboard fires cost $6 billion over 12 years period.[2]
- Ford class carrier generates three (3) times the power of a Nimitz class.
- USS New Orleans Fire in August 2025 which lasted 12 hours and resulted 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 Carrier[1]
- 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.

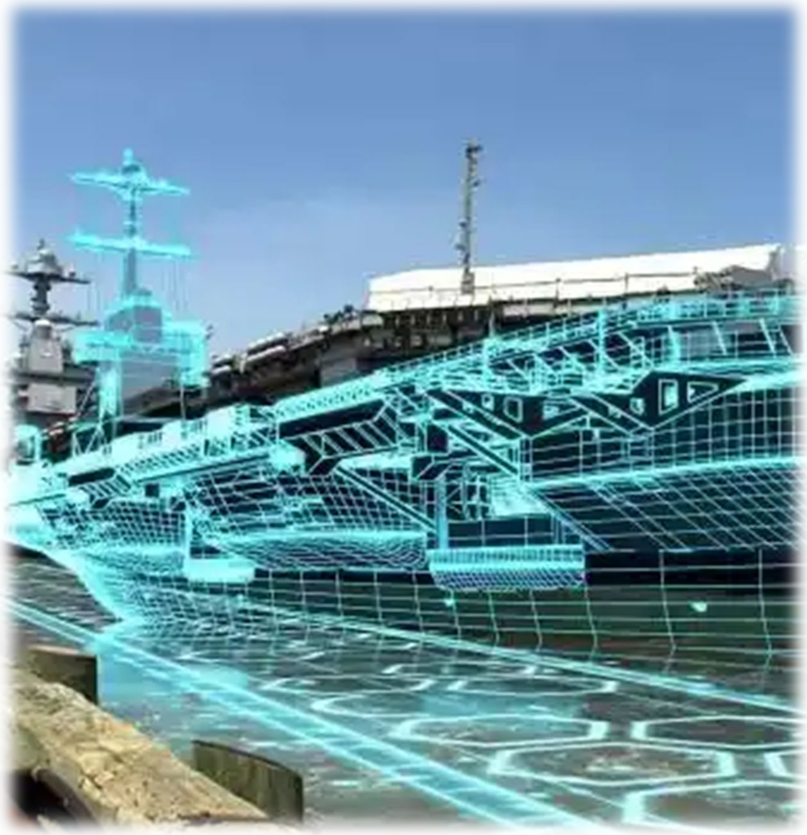


1. Huntington Ingalls Newsroom January 11, 2016
2. Joshua Carter, NSWCDD "Towards an Intelligent Shipboard Nervous System: Distributed Fiber Optic Sensing", 24 October, 2022

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 Costs[1]
  - 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 historian 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.*

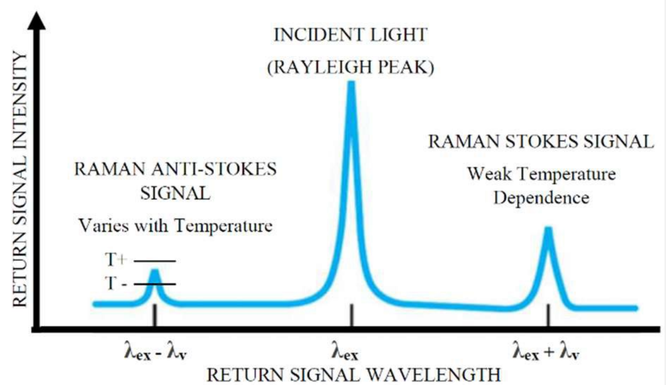
1. DoD Condition-Based Maintenance Plus Guidebook, August 2024
2. https://www.gao.gov/products/gao-25-106990

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 7 at completion of RA 2025-04 → After RA 2026-02: **TRL 8**
- 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…

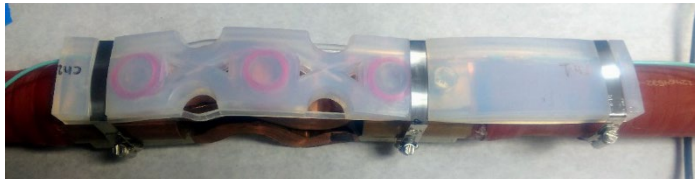
MIL-DTL-32772: 3.6.13 Non-contact thermal sensors. When specified (see 6.2), fiber optic temperature sensors or other technologies shall be provided to determine temperatures of selected current carrying joints or expected hot spots (see 4.4.3.8.7). ***Temperature sensors shall be permanently mounted***

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, VisTech, PSU EOC, AP Sensing: DTS Installation on test site.
- **2026* - RSL Fiber Systems**, NAVSEA 05Z33, NSWC DD, Austal, VisTech, PSU EOC, AP Sensing: DTS Installation on marine vessel.

* NSRP Research Announcements

INSPECTION OF ELECTRICAL ASSETS

NSRP Efforts Timeline vs. Cost of Arc-Flash[1]

Item	DESCRIPTION	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
1	PP 2015-437Safer Insp. of MV Switchboards															
2	PP 2017-422 DTS for Insp. of El. Panels															
3	RA 2019-376-01 DTS for IBP Connections															
4	RA 20-01 DTS for IBP to Equip. Connections															
5	PP 2019-477-004 DTS for CBM of El. Panels															
6	RA 2025-04 DTS Installation on Land Site															
7	RA 2026-02 DTS Installation on Vessel															
8	DTS System Qualification															
9	Full Fleet Implementation															
CUMULATIVE COST OF ARC FLASH ($ 000,000)		4.5	9.0	13.5	18.0	22.5	27.0	31.5	36.0	40.5	45.0	49.5	54.0	58.5	63.0	67.5

[1] Cumulative Costs Do Not include costs of fires caused by arc-flash.

Arc-Flash Event Costs

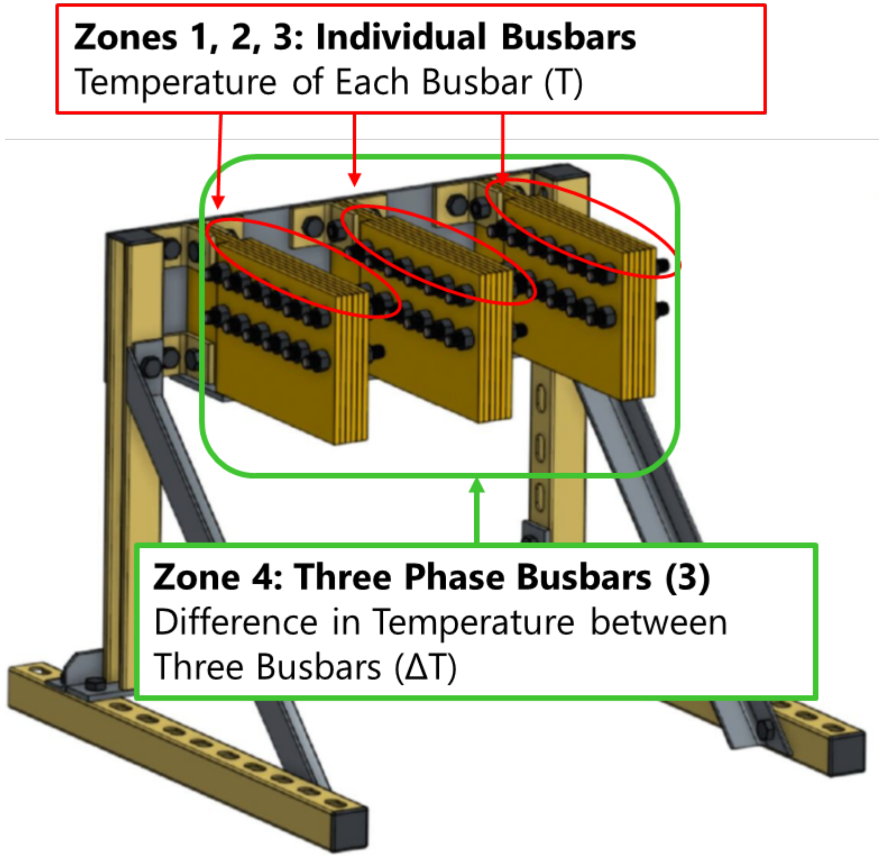
Labor (160 hrs.)	$16,000
Hardware/Parts	$150,000
Ship Delay (4 days)	$400,000
Est. Total	$566,000

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	≥ 70°C	Failure Imminent	****	Equipment should be secured immediately and not operated until repairs are complete.
2	40°C to < 70°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°C	Failure Possible	**	Corrective action should be taken as soon as feasible.
4	10°C to < 20°C	Performance Degraded	*	Corrective action should be taken at next scheduled routine maintenance period or as schedule permits.
	< 10°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.

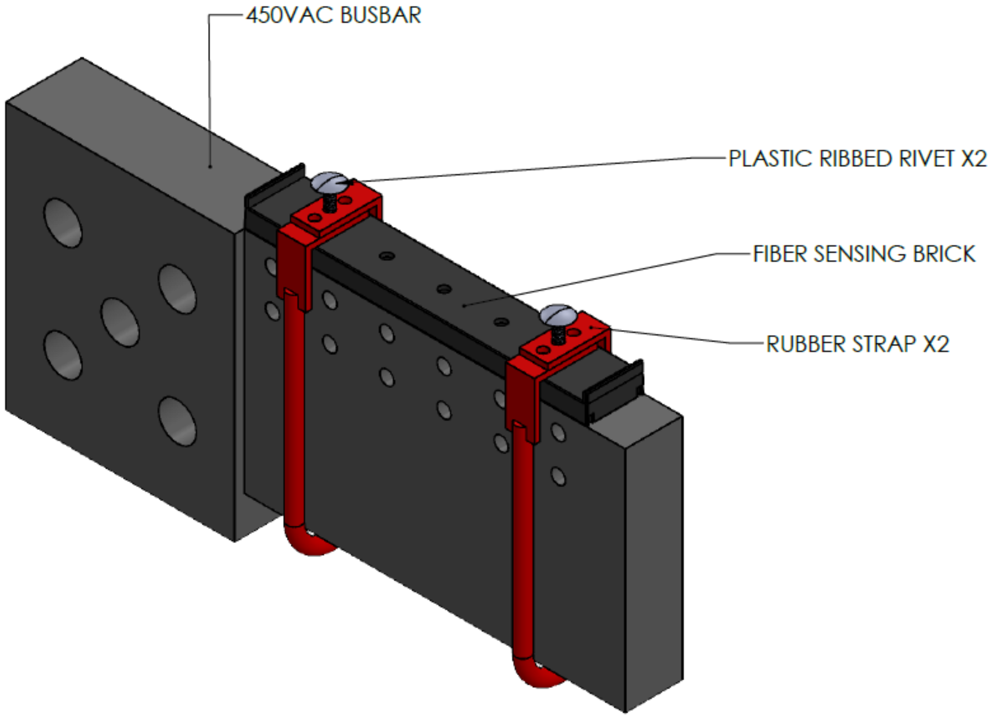
Task 3 – Configure the Monitoring Software and Graphical User Interface.

Task 4 - Installation at a Land Based Engineering Site (LBES).

DELIVERABLES

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

TASK 1 - ASSEMBLY DESIGN

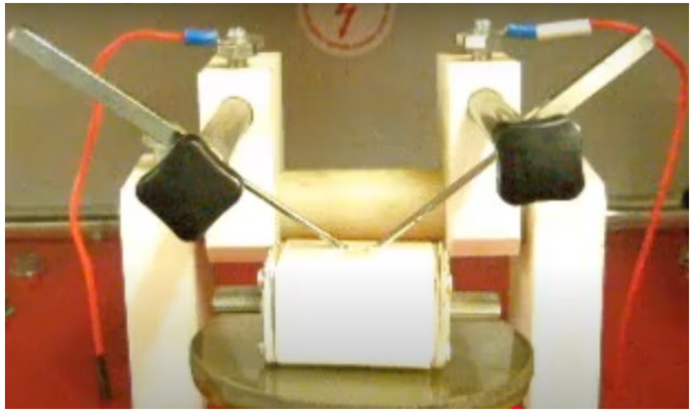


- Sensing Bricks to MIL-M-24519 (Materials used in Electric and Electronic Equipment).
- Attachment to Busbar to meet MIL-STD-901D Shock and MIL-STD-810 Vibration.

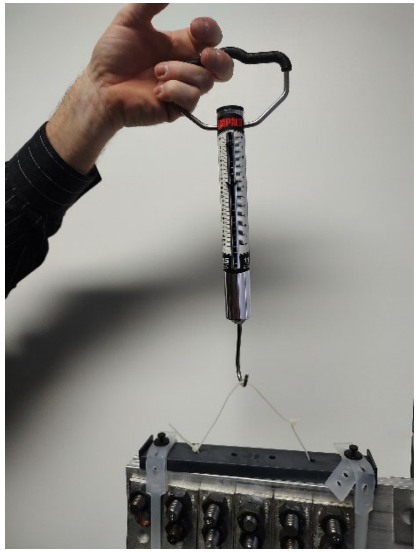
- ➢ Built assembly prototypes and confirmed fitting on Tactical LV Switchboards at LBES.
- ➢ Developed test method to determine heat transfer from loosening bolt(s) to sensing fiber.

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.



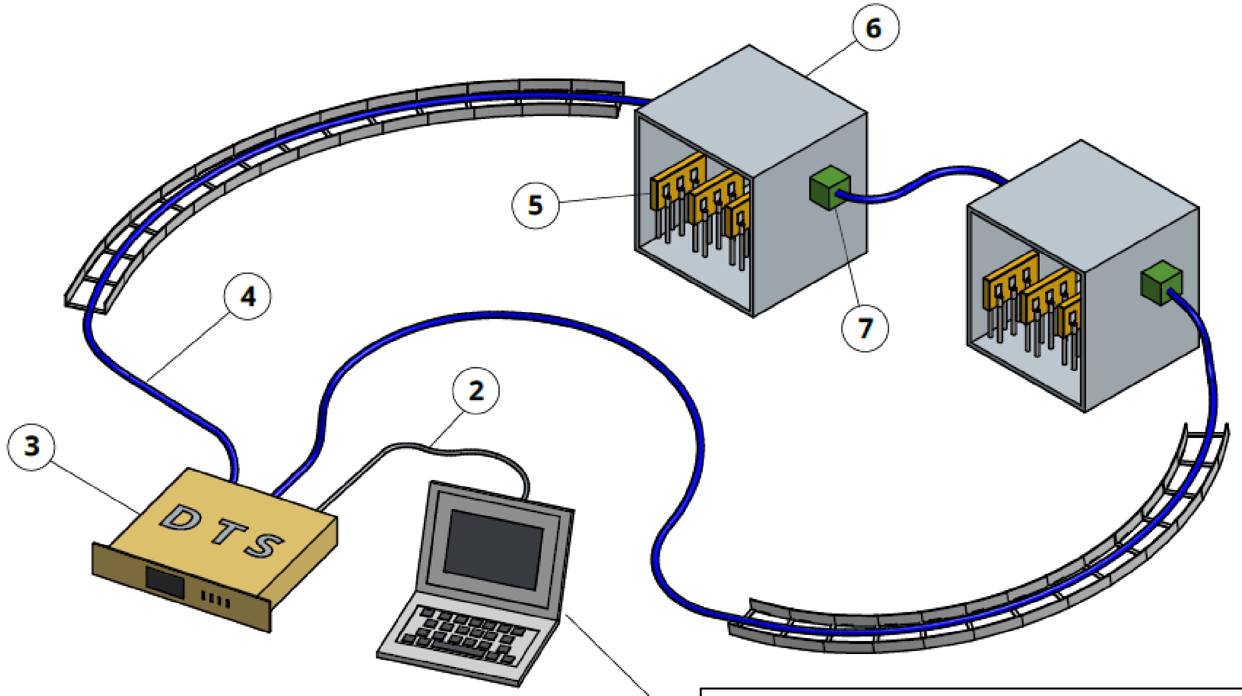
OBJECTIVE – Sensing bricks to pass **Shock & Vibration**.
- Straps of silicone to MIL-A-46146, (-45 to 200°C).
- 7 – 9 lbf of downward force. ≥65 G required to cause minimal movement of sensing brick.
- Run Shock & Vibration at AeroNav before on-ship install.



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

RSL ADVANCED LIGHTING TECHNOLOGIES



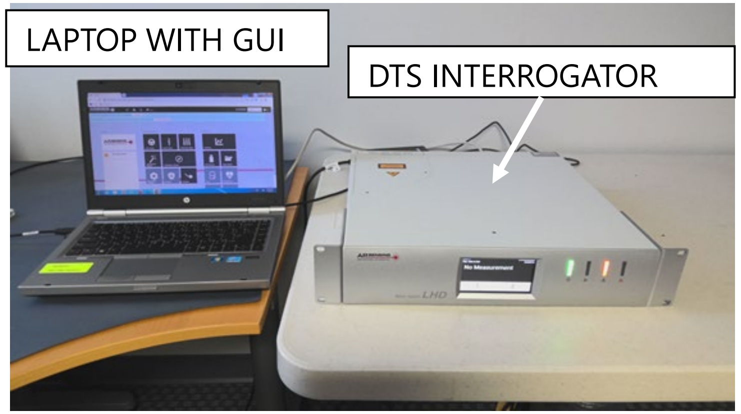
1	Laptop with GUI
2	Ethernet Cable
3	DTS Interrogator
4	M85045/18-01 (4)Fiber 62.5/125 Cable
5	3 Phase 450V Busbars
6	Electrical Switchboard
7	Fusion Splice Enclosure

- Two (2) DTS interrogators on same sensing assemblies' configuration for redundancy.

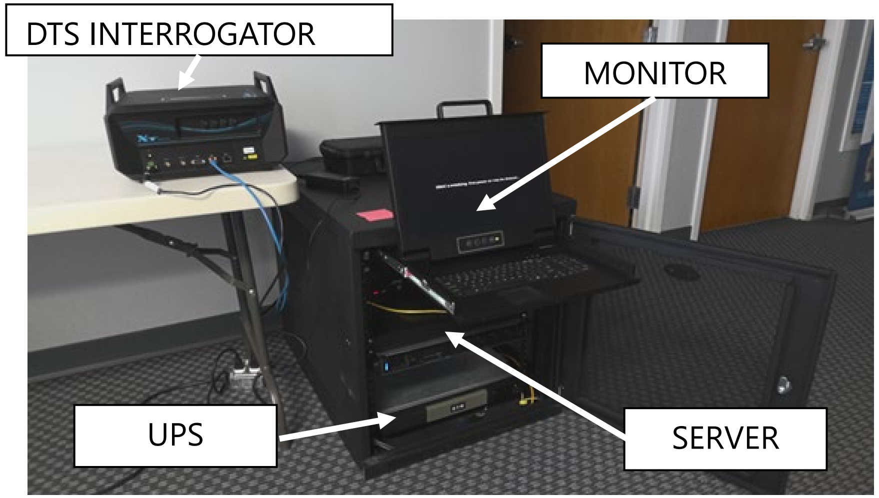
  Or
- **One (1) DTS interrogator sending sensing signal from two (2) channels for improved redundancy.**
- Multiple switchboards can be connected to same DTS channels.
- MIL-PRF-85045/18 transport fiber cable external to switchboards.
- M85045 cable spliced to internal fiber optic sensing cable assembly.

TASK 2 – DTS SYSTEM – HARDWARE SELECTION

ADVANCED LIGHTING TECHNOLOGIES



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)	1 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

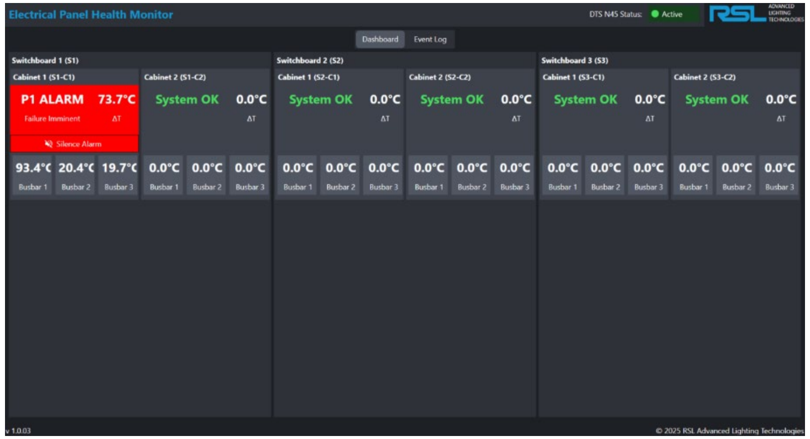
TASK 3 – CONFIGURE SOFTWARE AND GUI

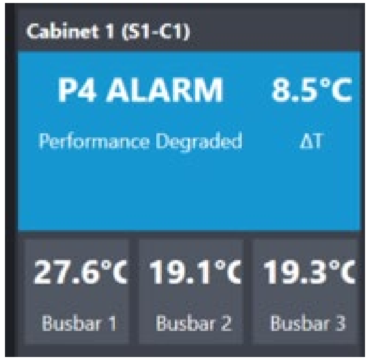
- Visual Technologies, Inc. contracted to develop software, GUI and historical trend logs.
- AP Sensing SmartVision not able to compare different sensing zones.
- Smart Vision is more suited for large area systems (Pipelines, Powerplants, Power Grids…)
- Software is DTS OEM agnostic.
- Used Modbus Communication protocol.

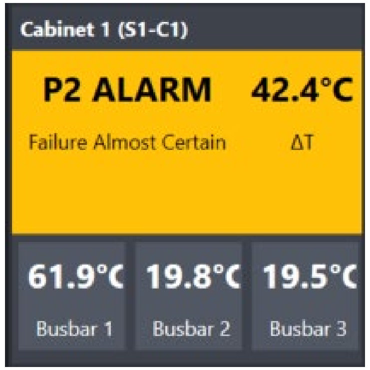
GUI MIL-STDs

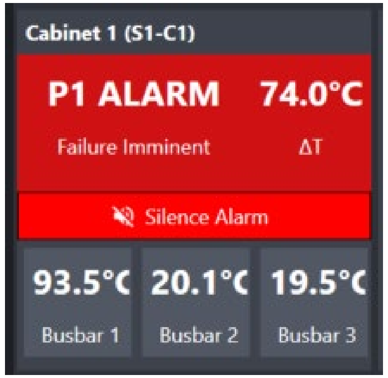
- MIL-STD-1472H "Department of Defense Design Criteria Standard Human Engineering"

Priority	Temp Rise or ΔT	Operational Assessment	Severity Code	Action	GUI Color
1	≥ 70°C	Failure Imminent	4	Equipment should be secured immediately and not operated until repairs are complete.	**Red / Audible Alarm**
2	40°C to < 70°C	Failure Almost Certain	3	Equipment should be secured if operating conditions permit otherwise monitored until corrective action can be taken.	Orange / Flashing
3	20°C to < 40°C	Failure Possible	2	Corrective action should be taken as soon as feasible.	Orange
4	5°C to < 20°C	Performance Degraded	1	Corrective action should be taken at next scheduled routine maintenance period or as schedule permits.	Blue
	< 5°C	N/A	N/A	No corrective action required; note for future reference.	Green

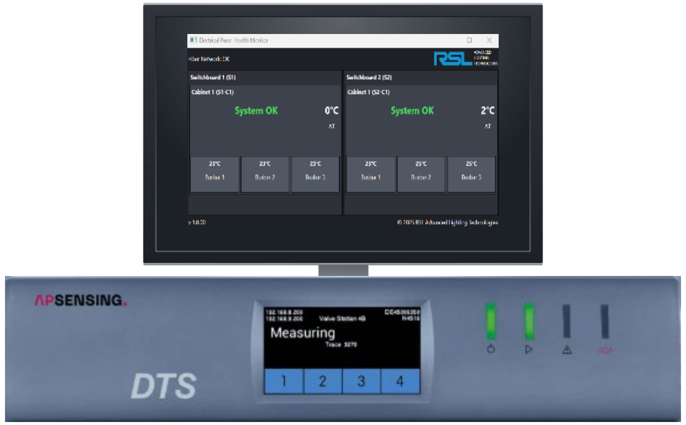








TASK 4 – Mockup DTS System



- 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.

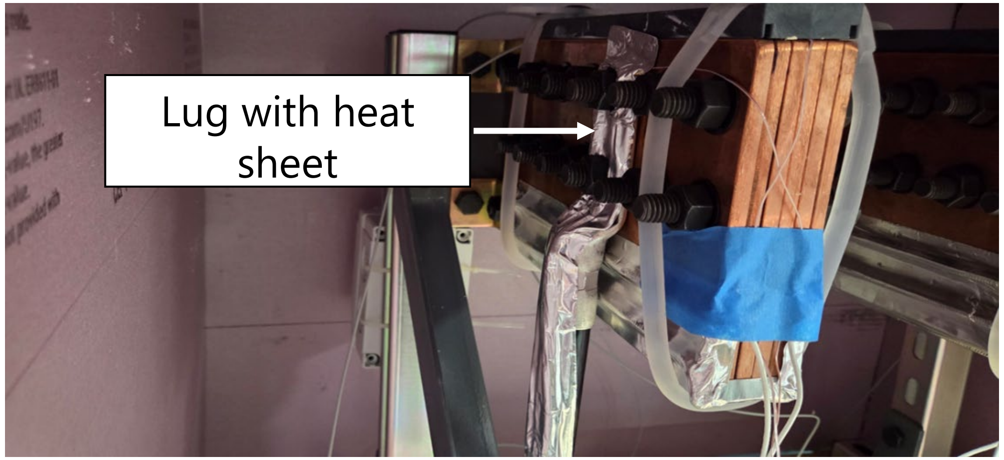
TASK 4 – INSTALLATION AND IMPLEMENTATION

Installation

- Used Busbars Mockup in RSL Fiber Systems' Lab

Operation

- Create conditions difficult and hazardous on energized switchboards.
- Make immediate changes to the sensing assembly installation configuration from observations during tests and simulation.
- Collect temperature data and logging of warnings and alarms.
- Make immediate changes to the software and GUI.
- Generate historical trend logs as baseline for CBM.
- Continue DTS system testing and evaluation after project completion.



NSRP RA 2026-02

ADVANCED LIGHTING TECHNOLOGIES

OBJECTIVE: configure, install, and operate a DTS system on a Naval Vessel to identify modification(s) required before the design is finalized, a specification document is created, and the system is qualified for full-scale implementation.

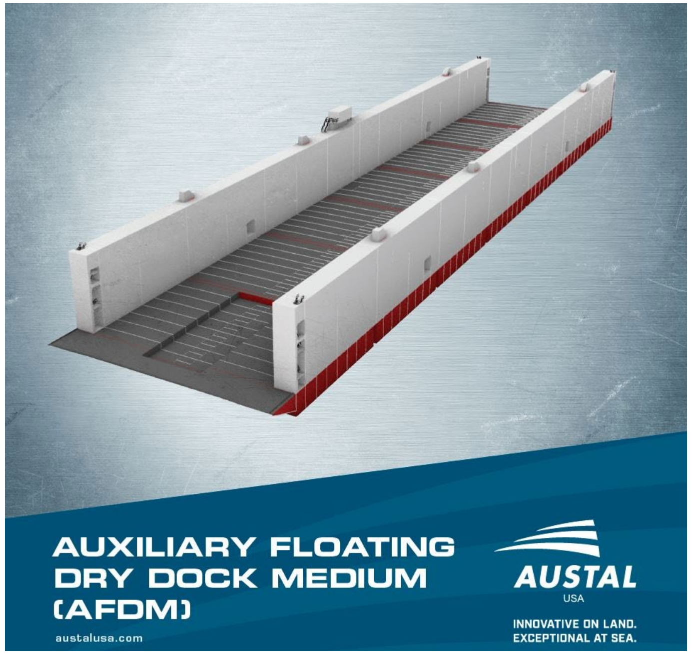
- **Task 1 – Training**
  - Train Shipyard personnel in installation and maintenance of DTS system.
- **Task 2 – Installation Planning**
  - Finalize vessel and plan installation.
  - Identify location of equipment, switchboards, cable routing, configure the cable assembly, GUI, and warnings/alarms.
- **Task 3 – Installation**
  - Install DTS interrogator, route transport cable (M85045/18-01) to switchboard, install cable assembly in switchboard, and verify the functioning of the cable assembly with an OTDR.
  - Map sensing zones, program alarms, and perform full system check.
- **Task 4 – Operation on Navy Ship**
  - Obtain feedback from ship and shipyard personnel on operation of system.
  - Make modifications as required.
- **Task 5 – Generate a Document Defining the DTS System Requirements**
  - Hardware requirements, Qualification testing, Installation procedures.
  - System set up, validation, acceptance testing, repair, and maintenance procedures.

DTS System ready for Qualification and Full-Scale Implementation

ON-SHIP INSTALLATION PLANNING

ADVANCED LIGHTING TECHNOLOGIES

- ✓Number of Switchboards and cabinets to be monitored
- ✓Routing configuration from switchboard to switchboard, cabinet to cabinet
- ✓Routing configuration from switchboard space to cable tray
- ✓Routing from cable tray to DTS interrogator location
- ✓Availability of M85045/18 cable available to splice into
- ✓Projected total length of fiber needed for installation



INSTALLATION AND OPERATION

- **Installation**
  - Up to two (2) days to install, set-up, and commission equipment.
- **Operation**
  - **No interference** with other functions/tests.
  - Baseline user manual.
  - Remote and on-site support.
- **Maintenance / Repairs**
  - No maintenance required / anticipated for duration of project.
- Leave in place or remove at end of project (~ ½ day required for removal)

TECHNOLOGY TRANSFER

ADVANCED LIGHTING TECHNOLOGIES

- 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)
- Proposed 2027 RA: DTS for fire detection.

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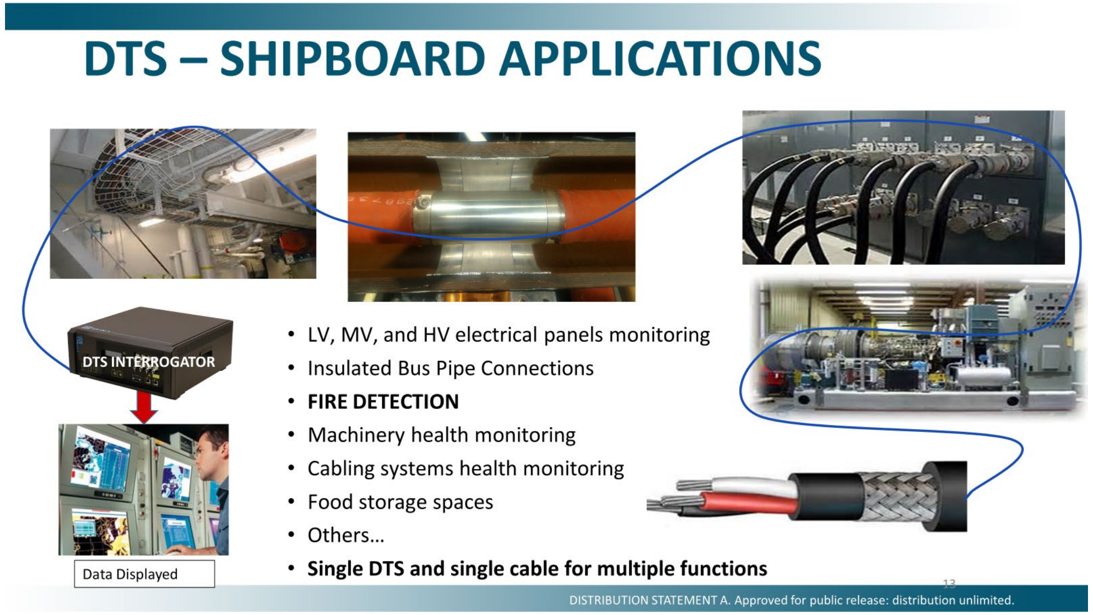

RETURN ON INVESTMENT

	Surface Combatants	Amphibius Warfare	Aircraft Carriers
PRE-IMPLEMENTATION COST	$3,050,625		
NO. OF DTS STSTEMS PER SHIP	2	4	6
INSTALLED COST (PER SHIP)	$293,040	$586,080	$879,120
NUMBER OF SHIPS	120	32	12
FULL FLEET IMPLEMENTATION	$67,519,425		

Description	As-Is Baseline	Post-Implementation
Arc faults per year (1):	8	-
Est Repair time (hrs.):	160	-
Days per repair:	4	-
Average Cost of delay per day:	$100,000	-
Cost per year:	$3,200,000	-
Cost of Ships' Fires over 12 years (2):	$6,000,000,000	-
Avg. annual cost:	$500,000,000	-

$$\text{ROI} = \frac{\text{Cost Reduction} - \text{Navy Investment}}{\text{Navy Investment}}$$

$$\text{ROI} = \frac{\$542{,}320{,}000 - \$67{,}519{,}425}{\$67{,}519{,}425} = \mathbf{7.0}$$

ROI with 5 Years Arc-Fault Elimination

USS Higgins - April 28, 2026
"…the electrical malfunction may have produced sparking or smoke that ceased once power was removed."(3)

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.
3. Cmdr. Matthew Comer, Spokesperson for the U.S. 7th Fleet, May 1, 2026.

QUESTIONS?

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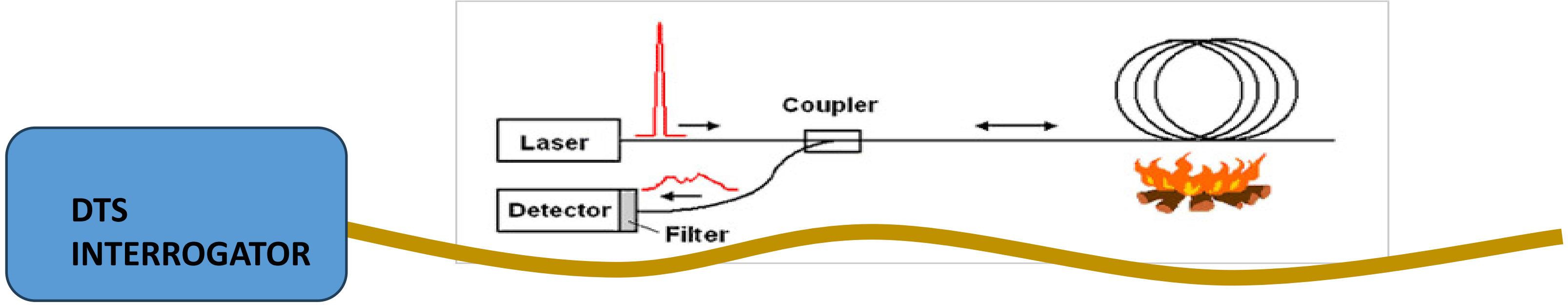
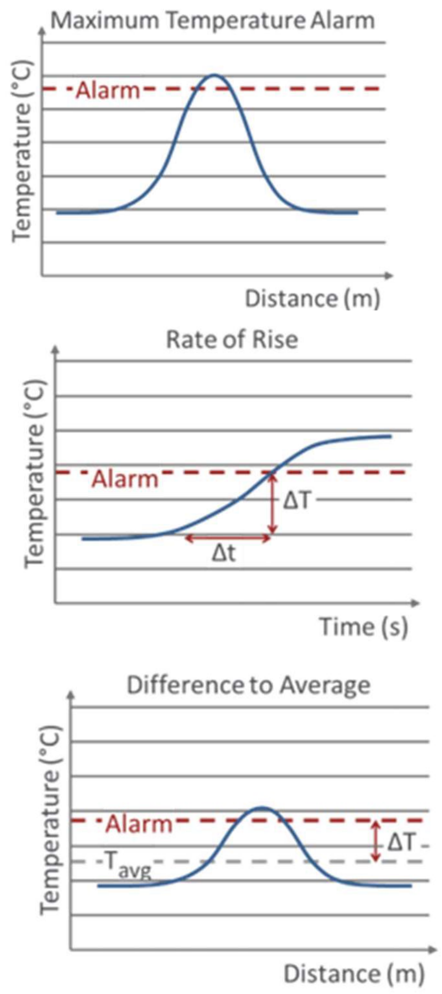
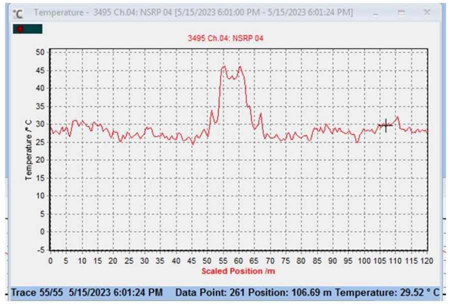
FIBER OPTIC DISTRIBUTED TEMPERATURE SENSING

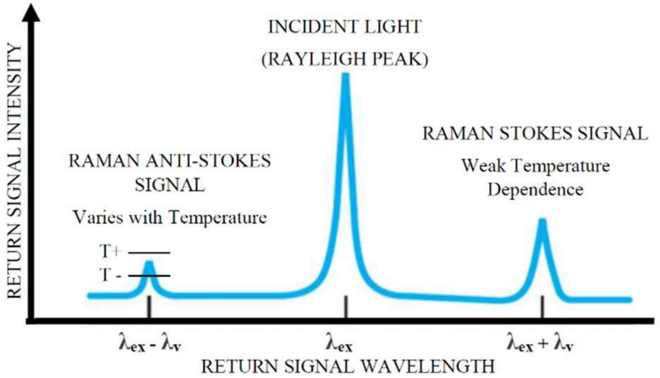
ADVANCED LIGHTING TECHNOLOGIES





- 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.





ROI BACKUP DATA

Description	As-Is Baseline	Post-Implementation
Avg. No. of Electrical Switchboards on Navy Ships:	16	16
Est Inspection time (hrs.):	16	2
Labor Cost ($/hr.):	$100	$100
Inspections of ea. Switchboard per Year:	1	0.5
Est. Inspection Cost per ship:	$25,600	$1,600
Total Surf. Fleet Inspection Cost per Year:	$4,198,400	$262,400
Arc faults per year (1):	8	-
Est Repair time (hrs.):	160	-
Days per repair:	4	-
Cost of Hardware and Replacement Parts per Arc Fault:	$150,000	
Cost of Labor and Material for Repairs per year:	$1,328,000	
Average Cost of ship delay per day:	$100,000	-
Cost of delays per year:	$3,200,000	-
Cost of Arc faults per year (labor, parts, delays):	$4,528,000	
Cost of Ships' Fires over 12 years (2):	$6,000,000,000	-
% of Fires Due to Arc Faults:	20%	-
Avg. annual cost of fires due to Arc-Faults:	$100,000,000	-
Avg. Annual Cost of Arc-Faults:	$104,528,000	-
Annual Cost of Arc-Faults + Inspections:	$108,726,400	
Five (5) Years Cost of Arc Faults:	$522,640,000	-
Five (5) Years Cost of Arc Faults + Inspections::	$543,632,000	