Safer Inspection of Medium-High Voltage Electrical Panels on Navy Ships

Penn State Electro-Optics Center

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NSRP ETP Panel Meeting
Omni Riverfront New Orleans, New Orleans, LA
December 2-3, 2014

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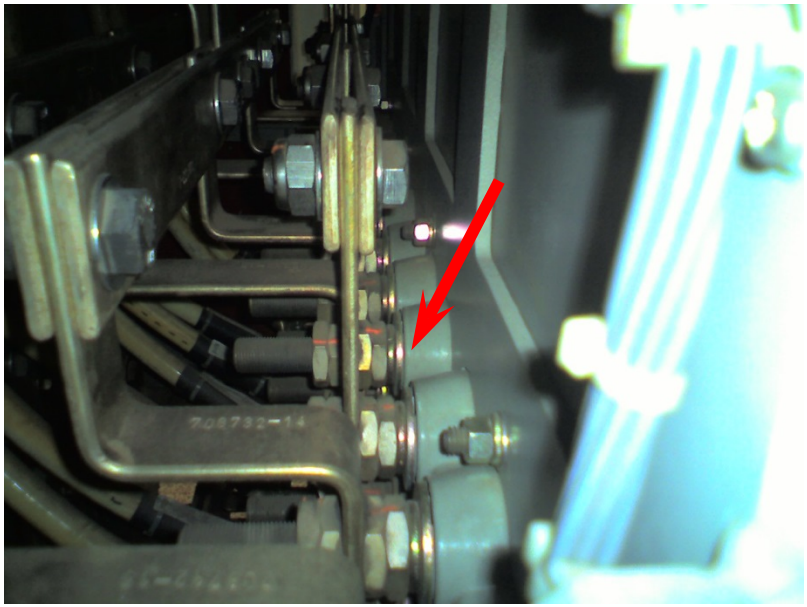
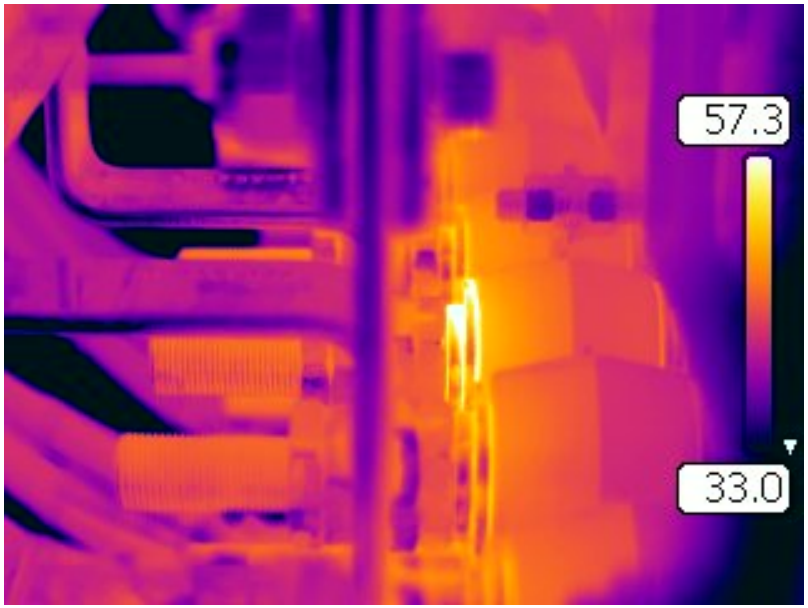
Background

- Even under best practices, installation of shipboard switchboards results in loose connections and wiring mistakes that lead to arc faults and other electrical maladies
  - Average of 8 arc faults per year throughout the navy fleet - all occurred in Switchboards and Load Centers - cost Navy millions of dollars in downtime and repairs [NAVSEA, Gulf Coast]
- Newer ships have electrical systems considered medium to high voltage, ranging from 4,000 to 13,000 volts
  - LPD and LHA = Medium, 4160 volt systems & CVN = High, 13000 volt systems
- Switchboard Inspections: during construction, builder's trial, during sea trials, and again at regular maintenance intervals
  - Current inspection methods: typically utilize Thermal IR imagers to investigate cabinets and comparatively identify 'hotspots'; other investigation modes require close proximity interrogation





Shore Power Switchboard

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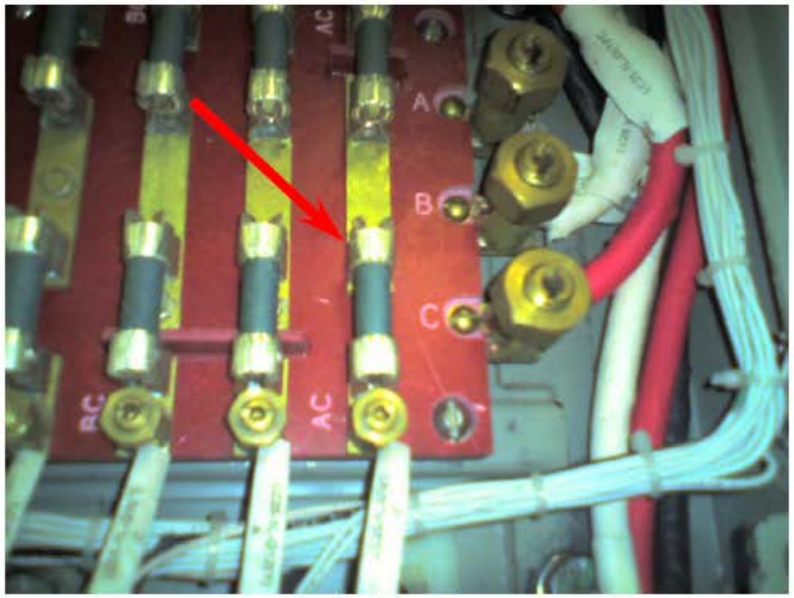
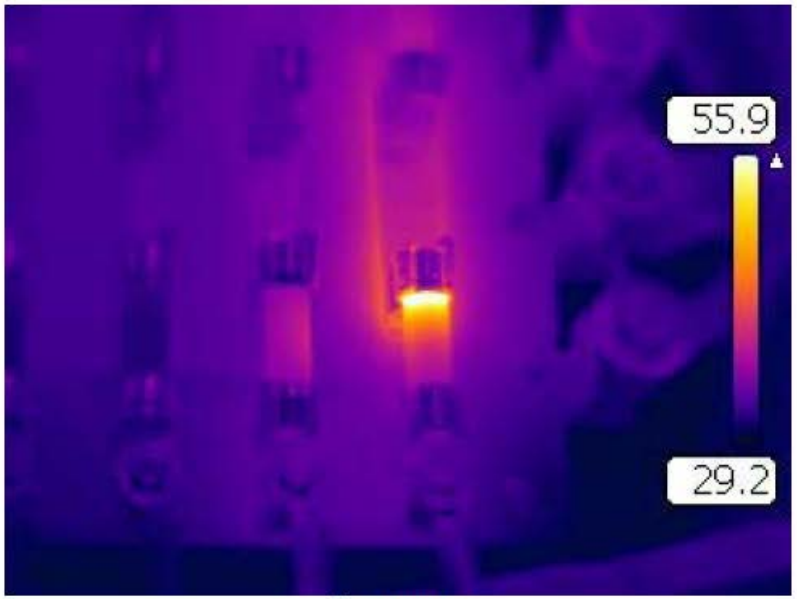
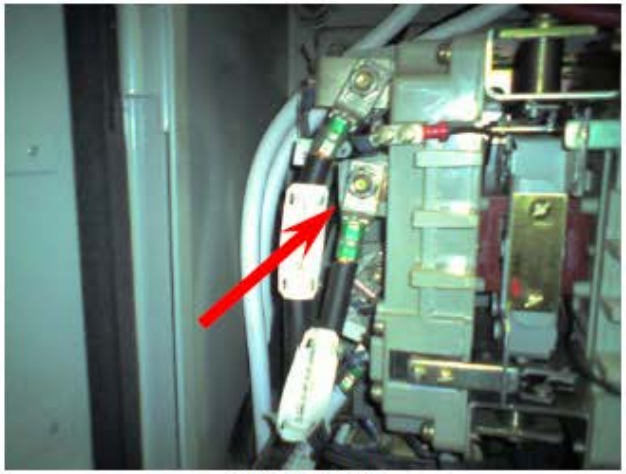


Photograph



Thermogram

Lighting Distribution Box



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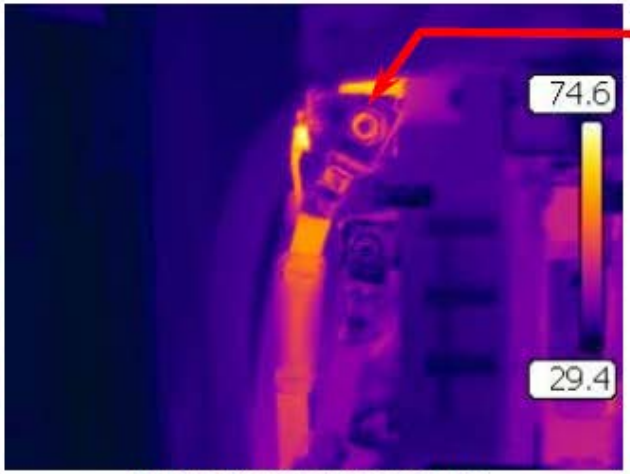

Before Repairs Thermogram

After Repairs Thermogram

Gear / Motor Controller

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Issue

- **Current Inspection Practices: secure the area, personnel don full coverage Personal Protective Equipment (PPE) to image inside active panels, preferably while drawing a high load such as during sea trials**
  - **Necessitates a new paradigm in switchboard inspection to comply with OSHA regulations and avoid Technical Warrant Holder (TWH) waiver requests**

Approach

- **EOC's initial analysis identified preliminary requirements and potential solutions for both "temporary" installations acceptable before and during sea trials as well as "permanent" solutions which must be compliant with Mil-Specs for shipboard operations**
  - **Leading candidate solution: temporary or permanent installation of panel covers with IR transparent windows enabling safe IR inspection without exposing personnel to active electrical components**
    - **This would allow inspectors in the room to operate at any time before/during acceptance/sea trials without PPE, while utilizing the same cameras and practices currently used but without the cumbersome and costly need to secure the area and deactivate and reactivate electrical switchboards.**
  - **Besides IR windows, potential solutions with pros and cons of each were identified including a standalone gantry for remote imaging, temperature sensitive paint, and RF interrogation of embedded temperature sensors**
- **Candidate solutions were vetted through NSRP Electrical Technologies Panel (ETP) presentations and subsequent stakeholder interactions.**

With the support of this community, the approach was refined such that this project focuses on demonstration of temporary (or permanent) installation of panel covers with IR transparent windows enabling safe IR inspection without exposing personnel to energized electrical components

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Project Goals and Objectives

The suitability and the safety impact of using IR windows in electrical panels for thermographic inspection of electrical connections on Navy ships will be determined

1. **Develop *safer, cost effective solutions* with IR transparent viewports in electrical panel covers to reduce risk for government and shipbuilder inspection of onboard medium/high voltage electrical infrastructures**
   - Facilitate comprehensive inspections accomplished with less risk and reduced labor
   - Eliminate or reduce the need for secured locations, personal protective equipment (PPE), and waiver requests wrt OSHA standards
2. **Develop and *demonstrate a proof of concept* solution that meets temporary (or permanent) installation requirements for the shipbuilder/government implementers**
   - Utilize principal methods and practices currently employed but without the cumbersome and costly need to secure the area and deactivate and reactivate electrical switchboards
   - Inspections made with closed panels avoiding dangerous proximity to energized circuits
   - Allow inspectors in the room to operate at any time before/during acceptance/sea trials
3. **Establish the *business / safety case* and path to implementation for government and shipbuilder applications**
   - Develop the business case and risk reduction benefits for shipbuilder construction and government applications where inspection of electric switchboards, load centers, and transformers is necessary
   - Pursue industry support and buy-in with identification of vendors which can provide products that meet temporary installation requirements
   - Explore the criteria and viability for permanent installations within Mil Spec 16036L

Active Project Participants

Lead Investigators		
Jeff Callen	**Penn State Electro-Optics Center** Research and Development Engineer, Electrical Engineering and Systems Engineering	jcallen@eoc.psu.edu
Matthew E. DiGioia	**Penn State Electro-Optics Center** Engineering Project Manager, ManTech Sensors, Robotics, and Automation	mdigioia@eoc.psu.edu
Sponsoring Shipyard		
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Government Stakeholder		
Clay Smith	**SUPSHIP Gulf Coast** Engineering	david.smith@supshipgc.navy.mil
Project Technical Representative		
Richard Deleo	**Newport News Shipbuilding** Engineering Manager - Submarine Electrical	r.deleo@hii-nns.com

Integrated Project Team (IPT): Advisors and Other Stakeholders

Government Stakeholders		
Humberto Lopez	**Naval Sea Systems Command** NAVSEA 05Z32 Electrical Distribution Systems, Office of the Technical Warrant Holder, The Naval Systems Engineering Directorate (SEA05)	Humberto.Lopez@navy.mil
Dave Mako	**Naval Surface Warfare Center - Carderock** Ship Systems Engr Station, NSWCCD-SSES C937	Charles.mako@navy.mil
Industry Advisors		
Dennis Neitzel	AVO Training Institute, Inc. OSHA Authorized Maritime Trainer Principal Committee Member, NFPA 70E	Dennis.Neitzel@avotraining.com
Gary Weiss	DRS Power & Control Technologies, Inc. Business Development Manager for Power Distribution and Power Conversion	garypweiss@drs.com
Other Interested Parties		
Greg Stevens	Bath Iron Works Electrical Engineering	Gregory.Stevens@gdbiw.com

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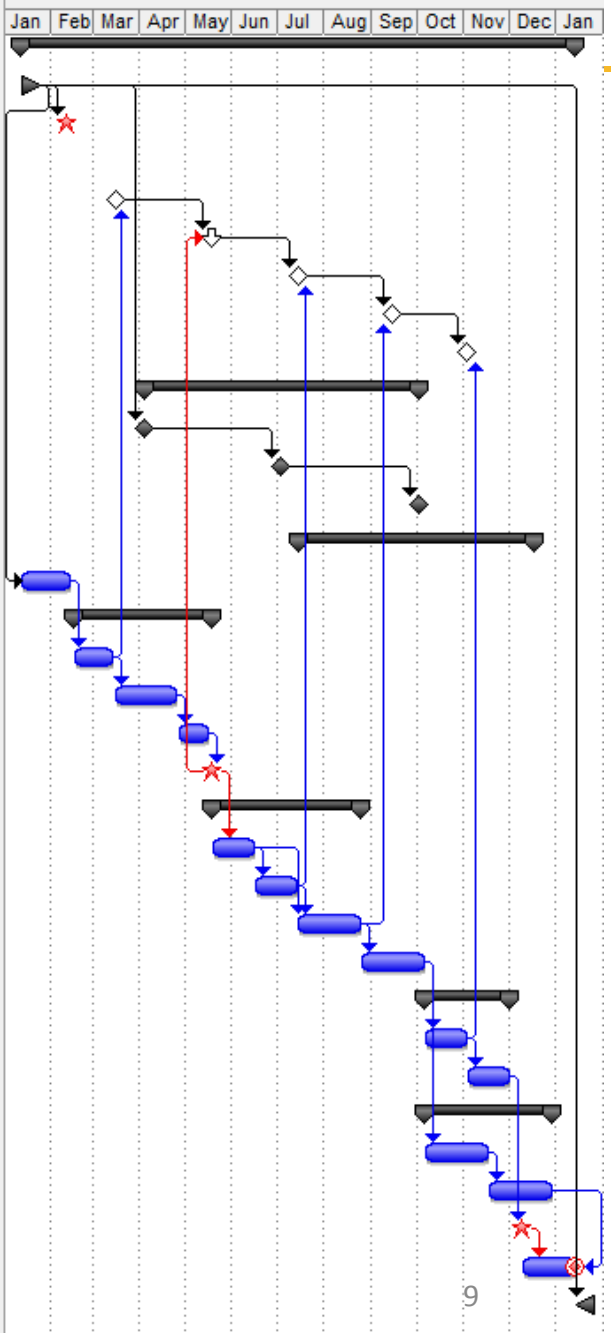
Process and Means to Accomplishing Goals and Objectives (from SOW)

1. **Review Shipbuilder/Government/Industry Requirements for IR Panel Inspection and Current Inspection Practices [HII, SSGC & Penn State EOC]**
   - Leverage the current state of the art in industry and the revised NFPA 70E criteria (National Electrical Code, "Standard for Electrical Safety in the Workplace")
2. **Determine Camera(s) and Window(s) to be Used [Penn State EOC Led]**
3. **Laboratory Tests of Cameras and Windows [Penn State EOC Led]**
4. **Devise Practical Implementation [Penn State EOC, HII & SSGC]**
   - Panel and window types, implementation, practical and operational considerations
5. **Plan and Prepare for Final Demonstration [Penn State EOC, HII & SSGC]**
6. **Develop Technology Transition Path Including Safety/Business Case [All]**

Schedule

	WBS	SOW Task #	Task Name	Start	Finish	Time
1	**1**		**Safer Inspection of Medium-High Voltage Electrical Panels for Navy Ships**	**Mon 1/12/15**	**Wed 1/13/16**	**12 Mos.**
2	1.1		Project Start: Funding Award is Received by All Parties	Mon 1/12/15	Mon 1/12/15	
3	*1.2*	*5.1.1*	*Kickoff Meeting (@ HII Pascagoula)*	*Wed 2/11/15*	*Wed 2/11/15*	1 day
4	**1.3**	**5.1.2**	**Bi-Monthly Teleconferences**	**Mon 3/16/15**	**Tue 11/3/15**	**2 Hrs Each**
5	1.3.1		1st Telecon (review requirements & camera selections)	Mon 3/16/15	Mon 3/16/15	
6	1.3.2		Next Telecon = Technology Interchange Meeting (see Task 5.1.3)	Mon 5/18/15	Mon 5/18/15	
7	1.3.3		2nd Telecon (review finalized lab experiments plans)	Wed 7/15/15	Wed 7/15/15	
8	1.3.4		3rd Telecon (review lab results and practical implementation concerns)	Tue 9/15/15	Tue 9/15/15	
9	1.3.5		4th Telecon (review plans for final demo)	Tue 11/3/15	Tue 11/3/15	
10	**1.4**	**6.2**	**Quarterly Reports**	**Fri 4/3/15**	**Fri 10/2/15**	
11	1.4.1		Quarterly Report 1	Fri 4/3/15	Fri 4/3/15	
12	1.4.2		Quarterly Report 2	Fri 7/3/15	Fri 7/3/15	
13	1.4.3		Quarterly Report 3	Fri 10/2/15	Fri 10/2/15	
14	**1.5**		**NSRP ETP Meetings (Qty. 2)**	**Wed 7/15/15**	**Thu 12/17/15**	**3 Days Ea.**
17	**1.6**	**5.2**	**Review shipbuilder/govt/industry requirements for IR inspection**	**Mon 1/12/15**	**Fri 2/13/15**	**1 Mo.**
18	**1.7**	**5.3**	**Determine camera(s) and windows to be used**	**Mon 2/16/15**	**Mon 5/18/15**	**3 Mos.**
19	1.7.1	5.3.1	Determine cameras to be used	Mon 2/16/15	Fri 3/13/15	1 Mo.
20	1.7.2	5.3.2	Research IR window types and materials	Mon 3/16/15	Fri 4/24/15	5 Weeks
21	1.7.3		Devise Preliminary Laboratory Test Plans	Mon 4/27/15	Fri 5/15/15	3 Weeks
22	**1.9**	**5.1.3**	**Technology Interchange Meeting (review plans) (@ EOC)**	**Mon 5/18/15**	**Mon 5/18/15**	**1 Day**
23	**1.8**	**5.4**	**Lab test cameras and windows**	**Tue 5/19/15**	**Mon 8/24/15**	**3 Mos.**
24	1.8.1		Obtain Materials (assuming a procurement delay)	Tue 5/19/15	Mon 6/15/15	1 Mo.
25	1.8.2	5.4.1	Finalize lab experiment plans	Tue 6/16/15	Mon 7/13/15	1 Mo.
26	1.8.3	5.4.2	Perform tests on candidate windows	Tue 7/14/15	Mon 8/24/15	1 Mo.
27	1.9	5.5	Devise practical implementation	Tue 8/25/15	Mon 10/5/15	6 Weeks
28	**1.10**	**5.6**	**Plan and Prepare for Final demonstration**	**Tue 10/6/15**	**Mon 11/30/15**	**2 Mos.**
29	1.10.1	5.6.1	Plan Final Demonstration	Tue 10/6/15	Mon 11/2/15	1 Mo.
30	1.10.2	5.6.2	Prepare for demo (fab cover w/ window, test)	Tue 11/3/15	Mon 11/30/15	1 Mo.
31	**1.11**	**5.7**	**Develop Technology Transition Path including Business Case**	**Tue 10/6/15**	**Mon 12/28/15**	**3 Mos.**
32	1.11.1	5.7.1	Establish business case for temporary and permanent installations	Tue 10/6/15	Mon 11/16/15	6 Weeks
33	1.11.2	5.7.2	Develop Technology Transition Path (Included in Final Report)	Tue 11/17/15	Mon 12/28/15	6 Weeks
34	*1.12*	*5.1.4*	*Demo and Final Review Meeting (@ SUPSHIP GC) [Deliverable]*	*Tue 12/8/15*	*Wed 12/9/15*	2 Days
35	1.13	5.8, 6.3	Final Report Developed & Delivered [Deliverable]	Thu 12/10/15	Wed 1/13/16	5 Weeks
36	**2**		**Contract End Date**	**Wed 1/13/16**	**Wed 1/13/16**	**Month 12**



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Milestones

1. **~1/12/15: Contracts scheduled for award**
2. **~2/11/15: Kickoff Meeting tentatively scheduled to occur @ HII**
3. **Mar 2015: 1st Telecon (review requirements & camera selections)**
4. **May 2015: Technology Interchange Meeting (@ EOC)**
   - After finalizing cameras/windows with development of plans for laboratory testing
5. **July 2015: 2nd Telecon (review finalized lab experiments plans)**
6. **Sep 2015: 3rd Telecon (review lab results and practical implementation plans)**
7. **Nov 2015: 4th Telecon (review plans for final demo)**
8. **Dec 2015: Demo and Final Review Meeting (@ SUPSHIP GC) [Deliverable]**

Deliverables

1. **Proof of Concept Demonstration**
   - Showing a representative IR thermographic inspection using an IR window on a closed cover of a electrical panel
2. **Quarterly Reports: April, July, and October**
   - Three Quarterly Status Reports, covering the first 9 months of the project period of performance
3. **Final Project Report: Jan-16**
   - Content shall include a summary of research done, test methodology, test results, demonstration results, conclusions, recommendations, and technology transition path forward

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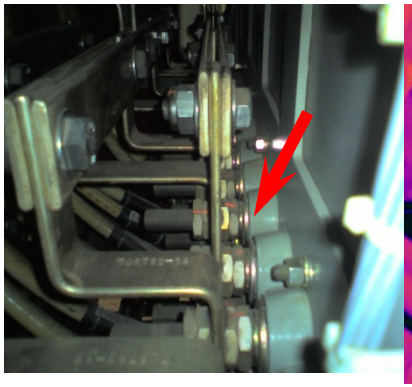

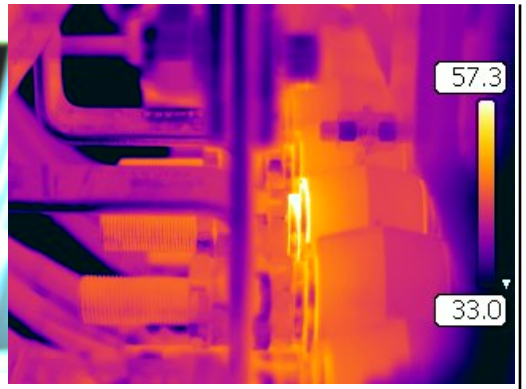

Average of 8 arc faults per year throughout the navy fleet - all occurred in Switchboards and Load Centers - cost Navy millions of dollars in downtime and repairs.

Current Inspection Practices: secure the area, personnel don full coverage Personal Protective Equipment to image inside active panels, preferably while drawing a high load such as during sea trials.

Sponsor: The National Shipbuilding Research Program 2014 Electrical Technologies Panel Project

Objective: Develop safer, cost effective solution within existing thermographic inspection practices for onboard medium/high voltage electrical infrastructures: utilize IR transparent viewports in electrical panel covers to reduce risk for government and shipbuilders

Performing Activities: Jan 2015 – Jan 2016, $150K

- Penn State Electro-Optics Center
- Ingalls Shipbuilding
- SUPSHIP Gulf Coast
- Newport News Shipbuilding
- Integrated Product Team Includes: NAVSEA (TWH Office), Naval Surface Warfare Center – Carderock, OSHA Safety Trainer, Industry Product Supplier

Tasks/Achievements:

- Review Shipbuilder/Government/Industry Requirements for IR Panel Inspection and Current Inspection Practices
  - Leverage the current state of the art in industry and the recently revised NFPA 70E criteria (National Electrical Code, "Standard for Electrical Safety in the Workplace"); emphasizes substantial risk reduction for workplace injuries and fatalities due to shock, electrocution, arc flash, and arc blast
- Laboratory Experimentation with Cameras and Windows
- Plan and Execute Final Demonstration of Practical / Representative scenario on a Navy ship
- Develop Technology Transition Path Including Safety/Business Case

Deliverables:

- Proof of Concept Demonstration: representative IR thermographic inspection using an IR window in closed electrical panel
- cover of a Quarterly Reports: April, July, and October
- Final Project Report: Jan-16

Implementation:

System:	Medium & High Voltage Electrical Infrastructures on Navy Platforms (LHD, LHA, CVN…)
Site:	LHA8 SUPSHIP-GC (Proof of Concept Demo)
Schedule:	Jan 2016 = Demo Results with Transition Plan for Temporary Installations
Status:	Intend future Insertion / adoption

Benefits / Payoff:

- Reduced safety risk to personnel: enables safer practices within existing inspection methods and procedures
- Potential to provide inspection process cost savings
- Applicable across multiple military domains & platforms with Information shareable across shipbuilder industry

RevA Nov14