S&T Efforts for Navy Corrosion Control

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Center for Corrosion Science & Engineering

NRL Code 6130

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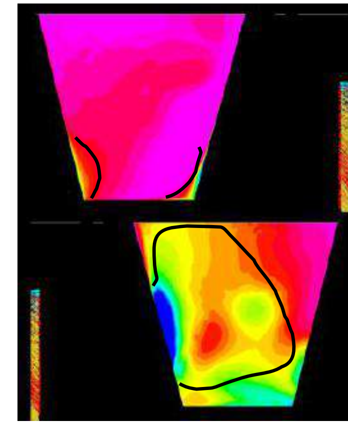
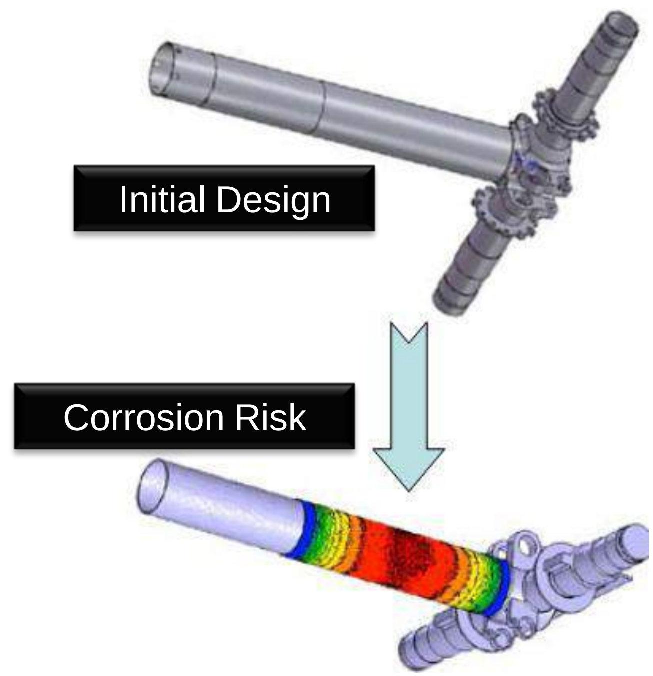
Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

Overview

- *Maintenance Reduction Technologies (FY08-FY12)*
  - Advanced Topside Coatings
  - High Temperature Non-Skid
  - Rudder Coatings



- *Corrosion Mitigation Technologies & Design Integration Future Naval Capability (FY12-16)*
  - Sprayable Acoustic Damping System
  - Corrosion Resistant Surface Treatment
  - Design Modules for Corrosion Prevention



Current Navy Topside Coatings

MIL-PRF-24635E, FED-STD-595C No. 26270 Haze Gray

- Single component, silicone alkyd copolymer
  - Provide camouflage and maintain appearance of ship
  - Low solar absorbance to reduce energy consumption

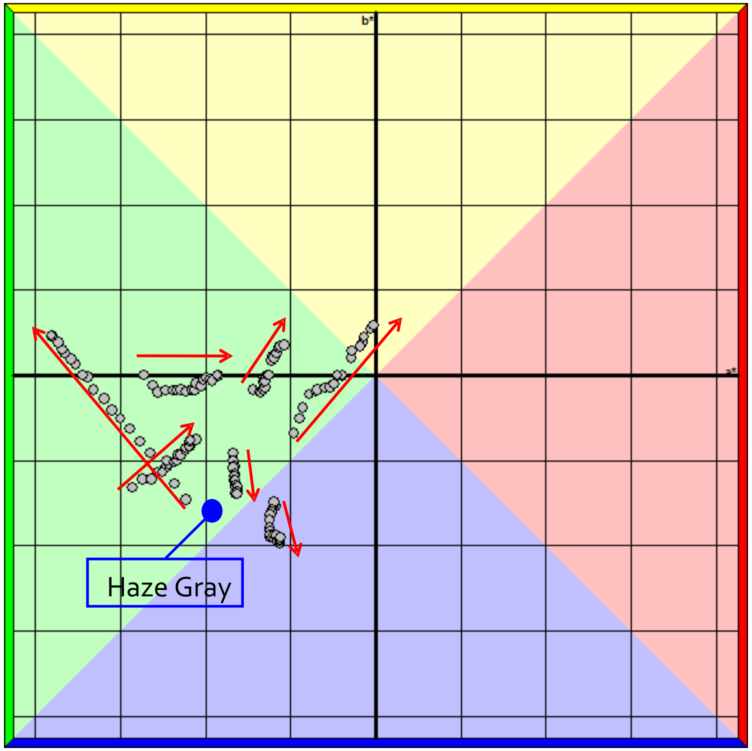
Poor Color-Matching Out-Of-The-Can & Poor Stability

Poor Performance → Constant Overcoating

Advanced Topside Coatings : Phase I Lab Testing

Commercial Products

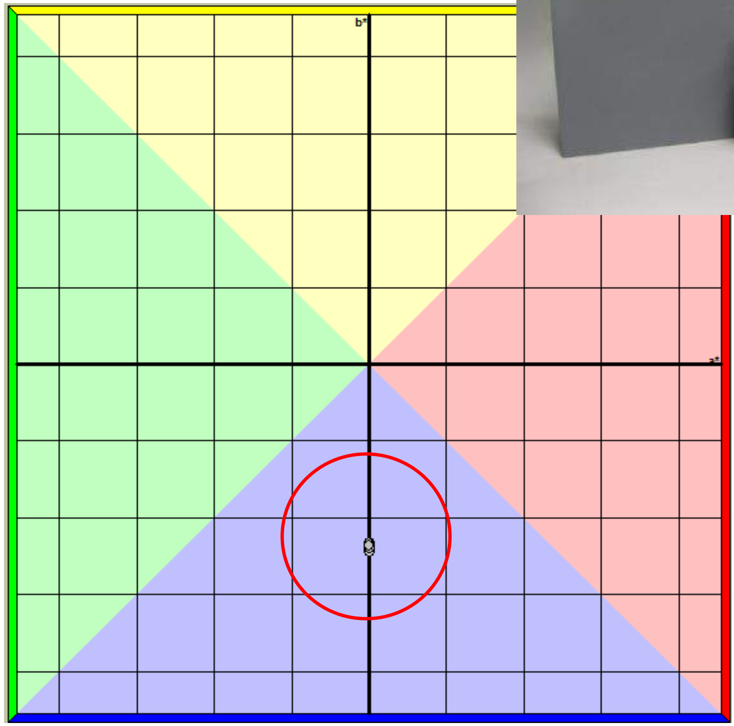
We 2000 HOURS WOM



BEST DOWN SELECTED FOR RETEST AND SHIP DEMO

NRL Polysiloxane

- 2Ksystem with commercially available materials
- Direct-to-metal (DTM) or over a primed surface
- Applied via spray, brush or roll
- 60° gloss of 60-70 GU

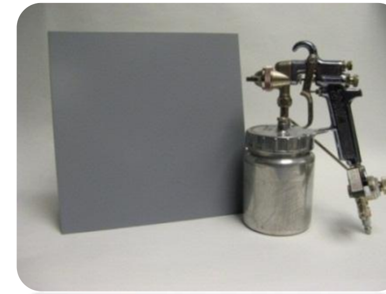


SHIP DEMO COMING AND REFORMULATION FOR COLOR MATCH & LSA

High Performance Topside Coatings

USS PONCE 1st Polysiloxane Demonstration, PPG - PSX 700

Developmental High Performance Topside Coatings



NRL Polysiloxane, Two component, depot level

- 2 component (2K) coating with stable LSA pigments
- Direct-to-metal (DTM) or over a primed surface
- Applied via spray, brush or roll (uses conventional spray equipment)
- Low VOCs (<95 g/L)

NRL Polysiloxane, Single component for Ships Force and maintenance painting (touch-up)

- Single component (1K) coating with stable LSA pigments
- Direct-to-metal (DTM) or over a primed surface
- Applied via spray, brush or roll (uses conventional spray equipment)

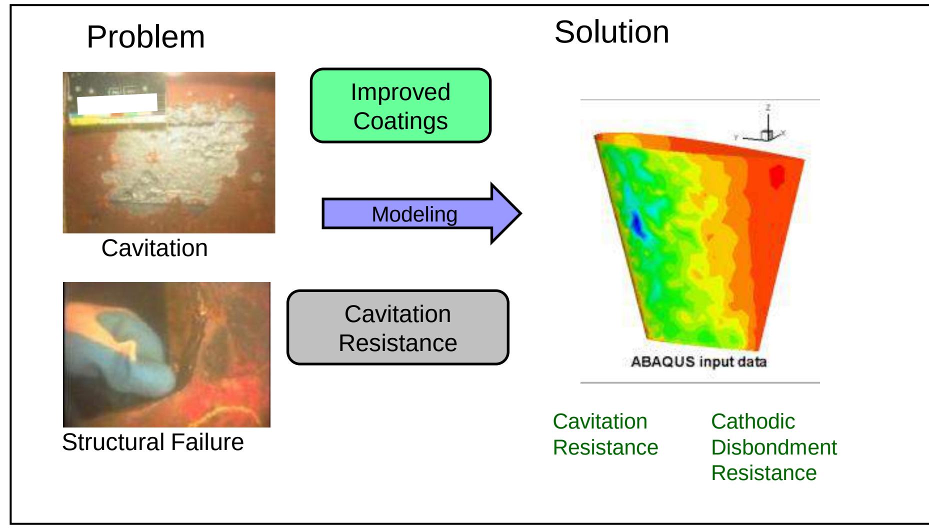
Advanced Topside Status

- 13 Products Tested AND 4 Products Identified as Improved Performance
- 3 Demonstrations Completed
- NRL Developed Systems are the front-runners
  - 1 Part and 2 Part High Solids Siloxane Formulations (TRL 5-6), FY11 Demonstration Planned
  - Solvent Free Polyaspartic System (TRL4)
- Topside Coating Maintenance is driven by corrosion AND aesthetics AND coating condition
  - Improved paints will have to be matched with improved maintenance practices
  - Improve assessment capability
  - Reduce unnecessary overcoating
- Need to demonstrate products and methodology on LARGE scale to realize improvements

Focus: Higher Gloss (<75), Cleanable, Color Stable, Color Matching Systems

Advanced Rudder Coatings

- **Problem:**
  - Rudder coating system fails in less than 2 year time period, which results in corrosion of the structure. This is the highest priority problem with the DDG 51 Type Desk at NAVSEA.
- **Objectives & Approach:**
  - Enhance performance coatings to provide minimum of 2 to 5 years service life on rudders.
  - Utilize computational model to predict forces & loadings on surfaces
  - Use stresses and deflections to design and validate test apparatus to replicate field conditions for use as screening test



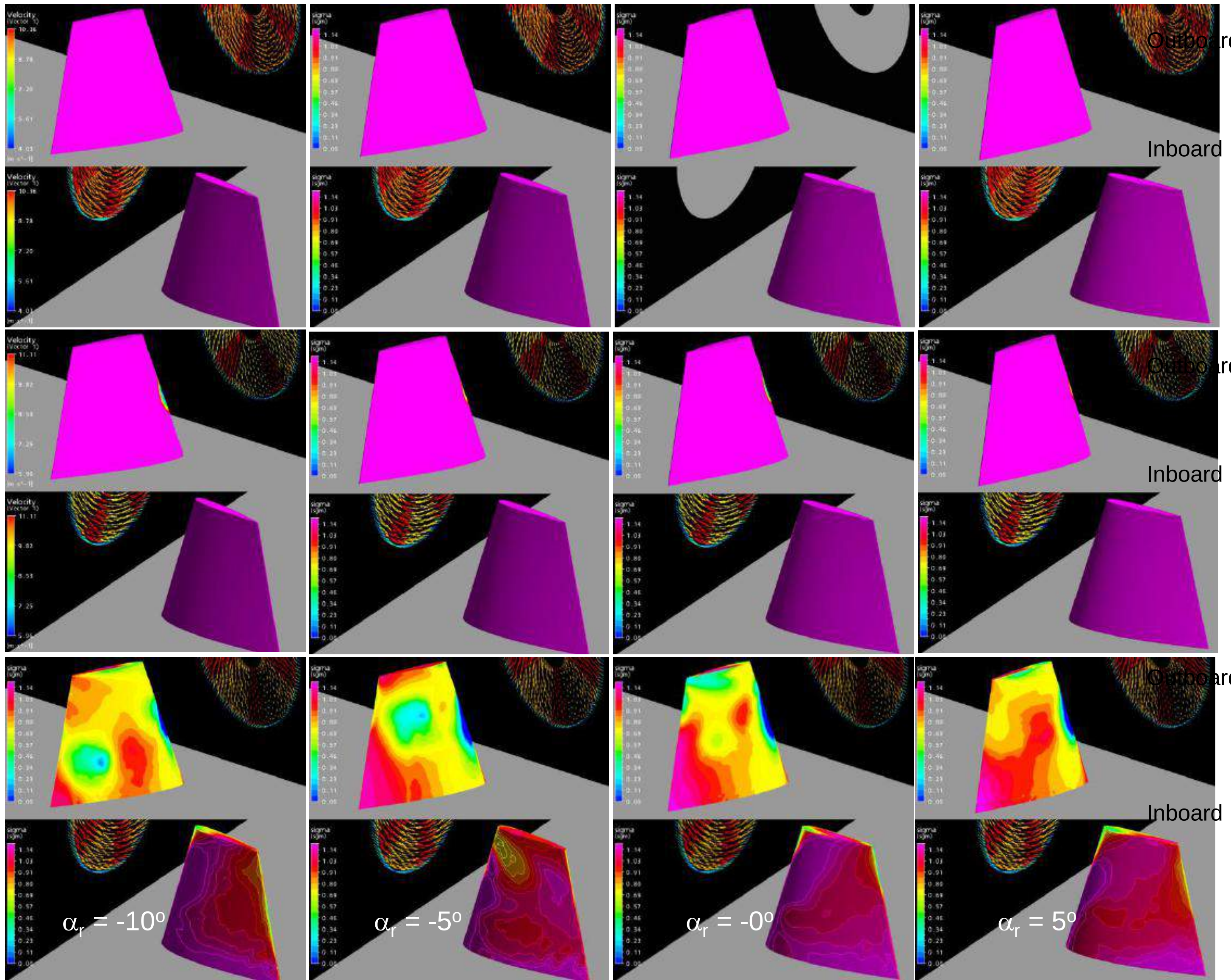
Rudder Coatings: CFD

Cavitation Coefficient with Velocity and Angle of Attack

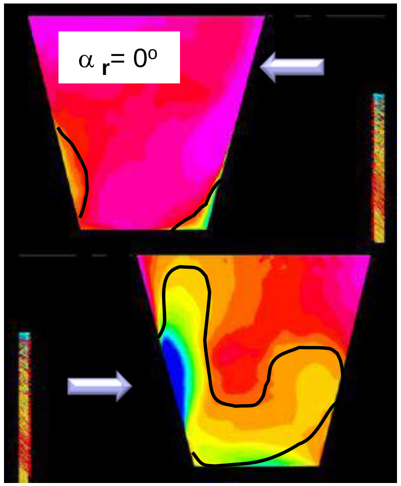
1/3 Speed Velocity (No cavitation)

2/3 Speed Velocity (Small area of cavitation on leading edge)

Standard Speed Velocity (Cavitation for all angles)



Development of Cavitation Initiation Area



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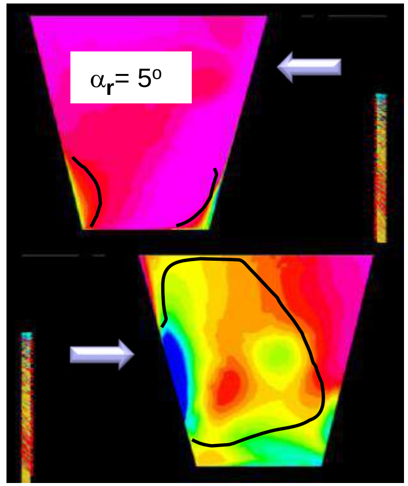

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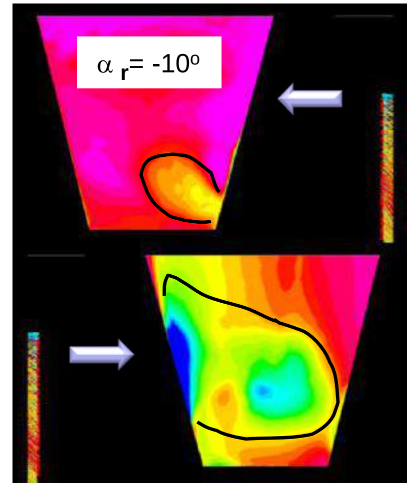

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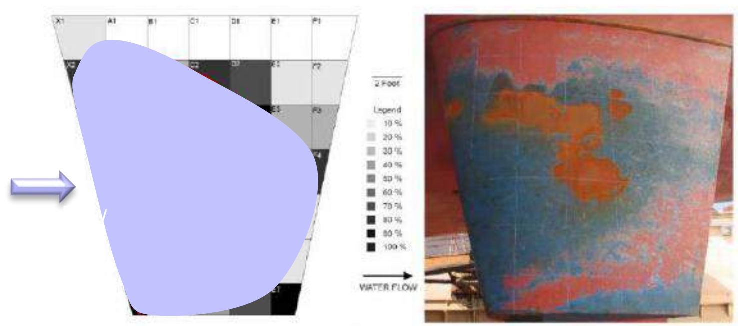
α_r = rudder angle

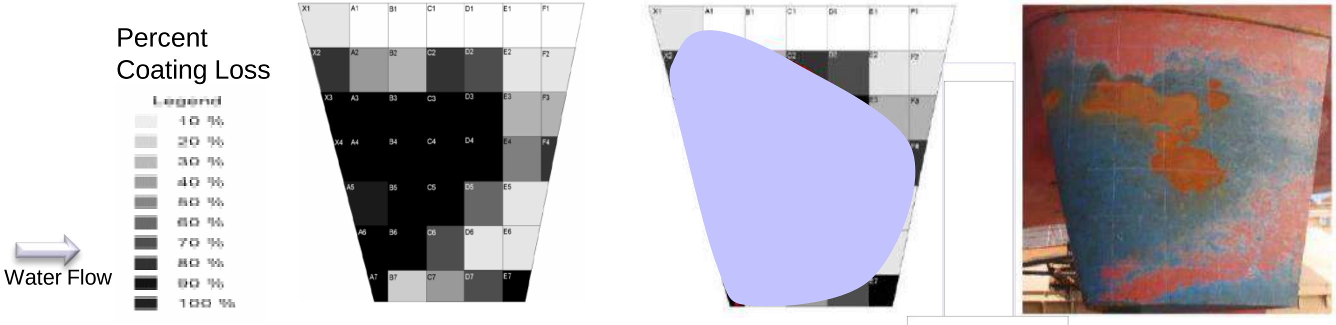
DDG 83 USS HOWARD
Port Rudder, Outboard Face
Anti-Fouling Coating Loss



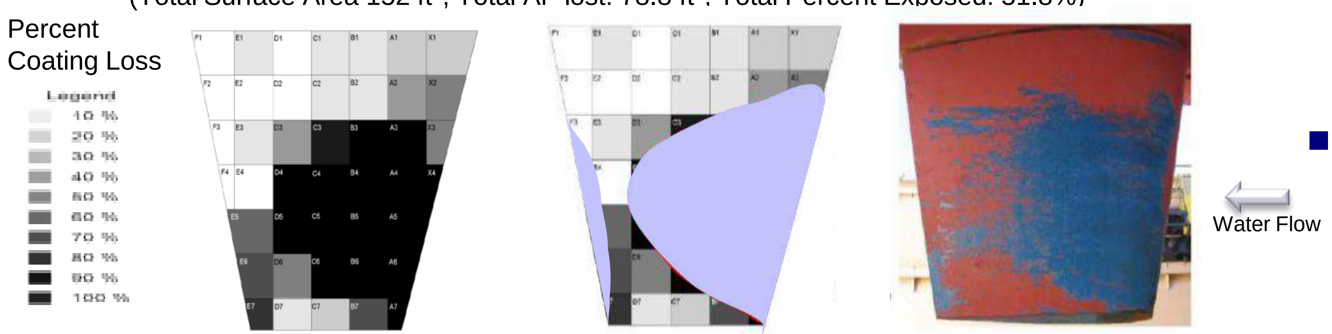
Total Surface Area: 152 ft²
Total AF Lost: 86.9 ft²
Total Percent Exposed: 57.0 %

Sheet Cavitation Regions Determined From CFD

DDG 83 USS Howard
Port Rudder, Outboard Face
Anti Fouling (AF) Coating Loss
(Total Surface Area 152 ft^2, Total AF lost: 86.9 ft^2, Total Percent Exposed: 57.0%)



DDG 83 USS Howard
Port Rudder, Inboard Face
Anti Fouling (AF) Coating Loss
(Total Surface Area 152 ft^2, Total AF lost: 78.8 ft^2, Total Percent Exposed: 51.8%)



- Based on port rudder computational model
- Combination of all load cases for 'life of ship'
- Fully wetted solution
- Conservative estimate of cavitation initiation
- Computational analysis valid for cavitation initiation only

Summary: Sheet Cavitation is primary initiator of damage, Structural Response is secondary.

NSWC Demonstration—Versalink P1000

Composite section with Versathane film is placed over notched troweled adhesive on MIL-P-24441 surface

USN R/V ATHENA

Final Installation

Vacuum Bag to Hold Section in Place for Cure

GREAT CONDITION!!!
VERSALINK COMPOSITE AFTER 1 YEAR ABOARD THE USN R/V ATHENA

ADVANCED RUDDER COATINGS: Road Forward

- *NSWC Code 65 success with Versalink P1000 provides light at the end of the tunnel!*
  - Pre-cast with adhesive to epoxy
  - Historically poor adhesion directly to epoxy
- NRL Modifications for Producibility
  - Modified pot life adequate for roll/brush/spray
  - Developed a tie coat to promote adhesion between the anti-corrosive epoxy coating layer and the cavitation resistant topcoat
  - Modified the Versalink to a sprayable topcoat, multi-pass single coat high build film (150 mils)
  - Utilize with anti-corrosive epoxy primer system resistant to cathodic disbondment.

GREAT CONDITION!!!
VERSALINK COMPOSITE AFTER 1 YEAR ABOARD THE USN R/V HELENA

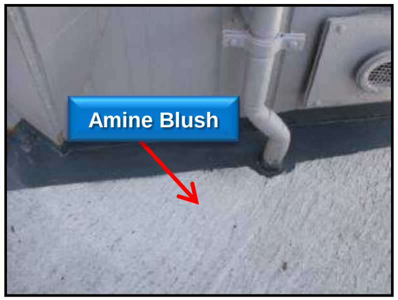
PLANNING FOR 2-3 DEMONSTRATIONS IN FY11:

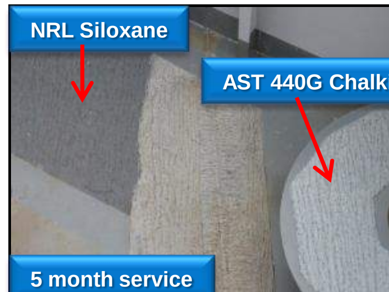
1. Pre-cast Sheet with Adhesive & Vacuum Sealed Cure
2. Brushed/Rolled Versalink over MIL-P-24441
3. Spray Applied over MIL-P-24441

High Performance Non Skid

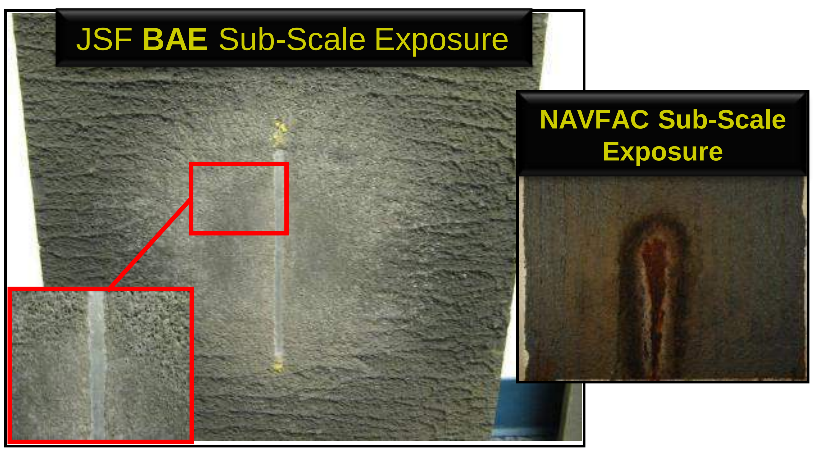
The Problem

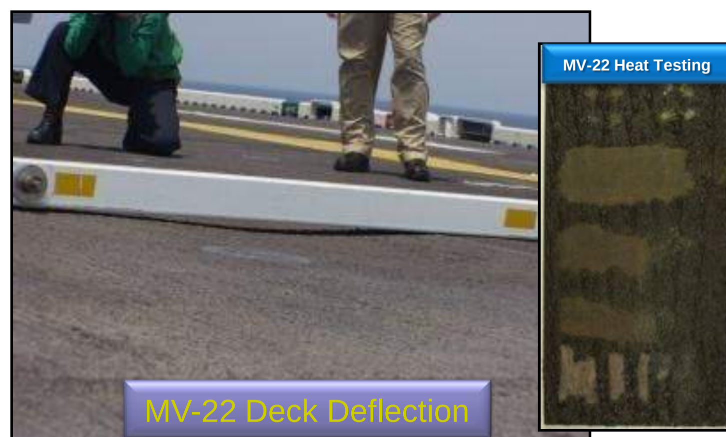
- Current nonskid products do not meet mission durability





- Current nonskid products can not support continuous JSF and/or MV-22 operations





Non Skid Testing & Selection

Extreme Durability,
High Durability Long Service Life

- ✓ Novolac Epoxy
- ✓ AST 660
- ✓ Hybrid Thermal Spray (Al-Ti HVOF, Zn Arc Wire, Fe Carbide Arc Wire)
- ✓ Aluminum Ceramic Thermal Spray
- ✓ NRL HD1 – Organo-siloxane
- ✓ Cementitious polymers

High Temperature Resistance, (MV-22 Specific)

- ✓ Midwest Thermal – 3-coat Thermal Spray
- ✓ Novolac Epoxy
- ✓ Thermion – Aluminum Ceramic Thermal Spray (TH604)

Extreme Temperature Resistance,
(F35B Specific)
7 Products Tested

- ✓ Thermion – Aluminum Ceramic Thermal Spray (TH604)

Novalac Epoxy

NRL HD1 (Rolled)

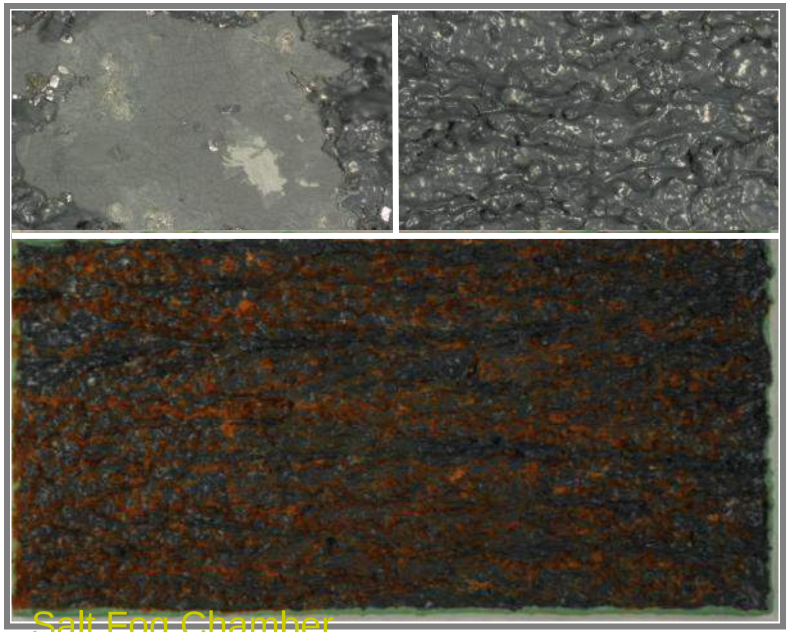
NRL HD1 (Sprayed)

Thermion

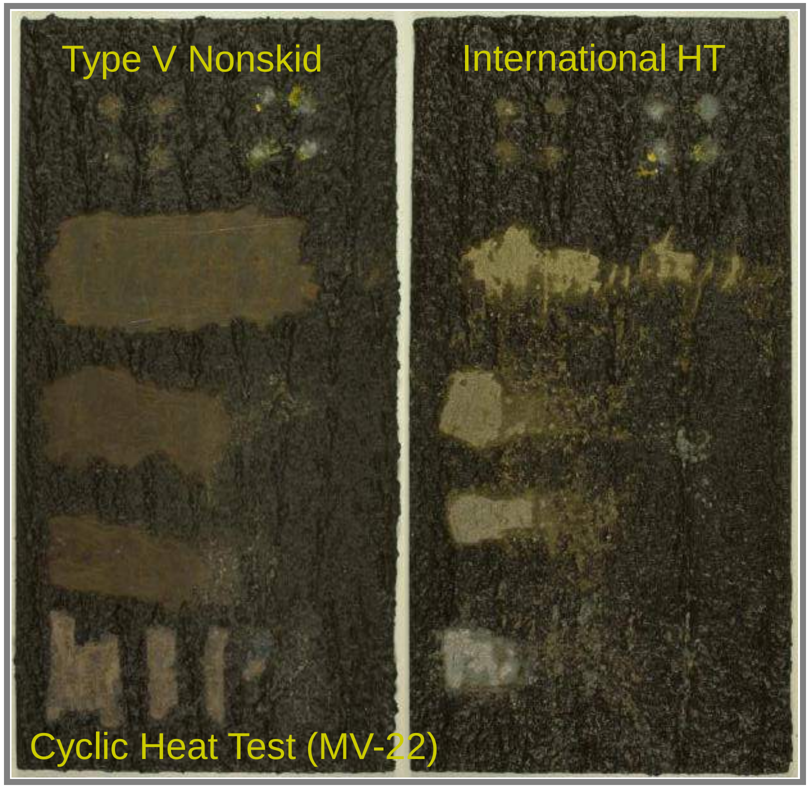
Hybrid Thermal Spray

Cementitious

Extreme Durability and High Temp (MV-22) Nonskid Coatings



Polysiloxane Nonskid and Primer
Applied by Napless Roller



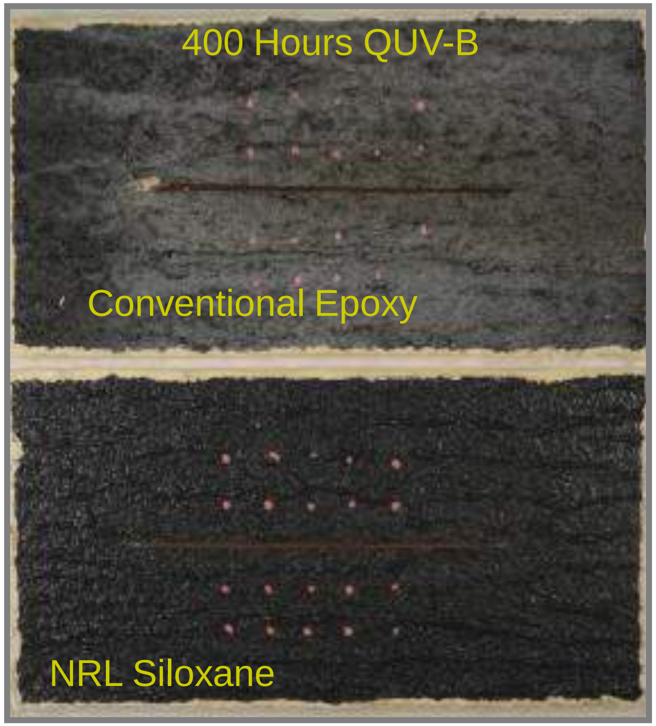
Silicone/Epoxy Hybrid Coating
Applied by Napless Roller

Extreme Durability Nonskid Coatings

Skid Pro

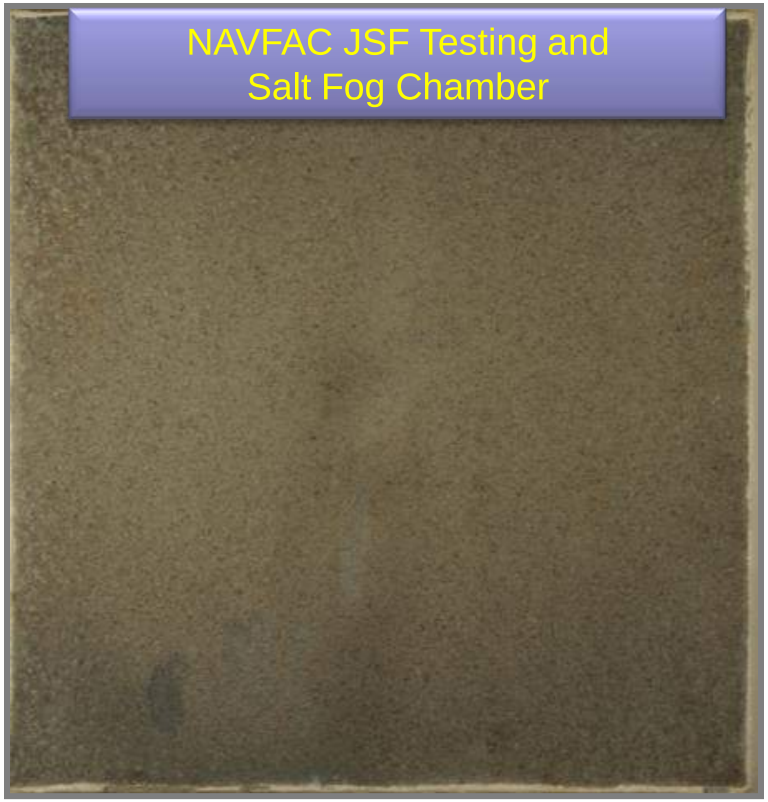
Cementitious polymer w/aggregate
Applied By Spray Equipment

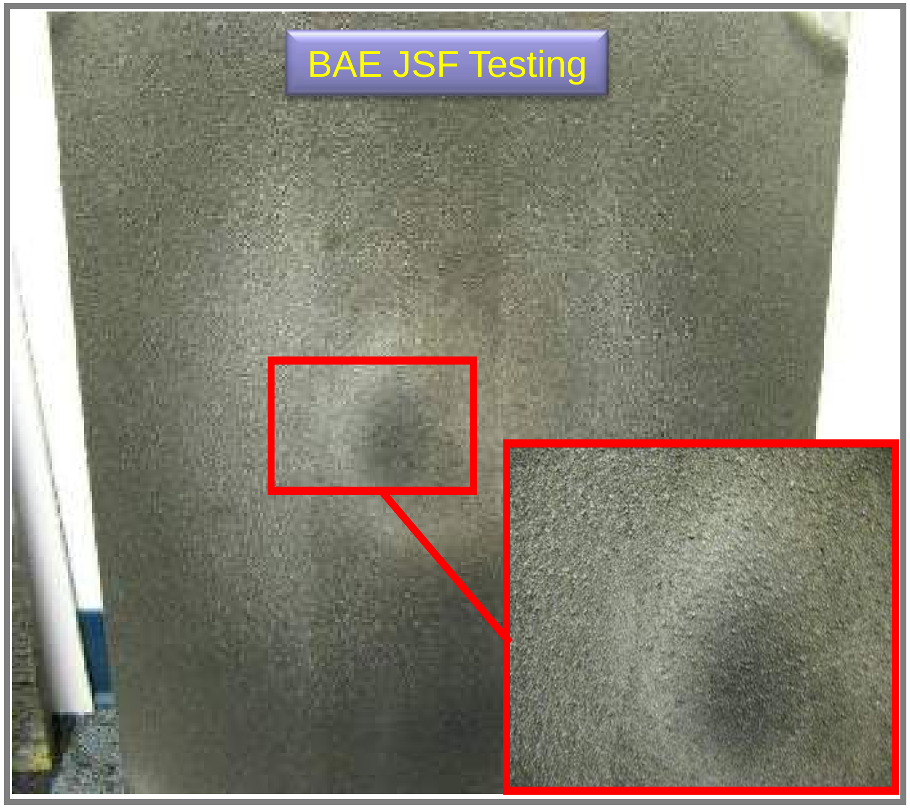
NRL Siloxane (Bottom)



Polysiloxane Base Resin
Applied By Napless Roller

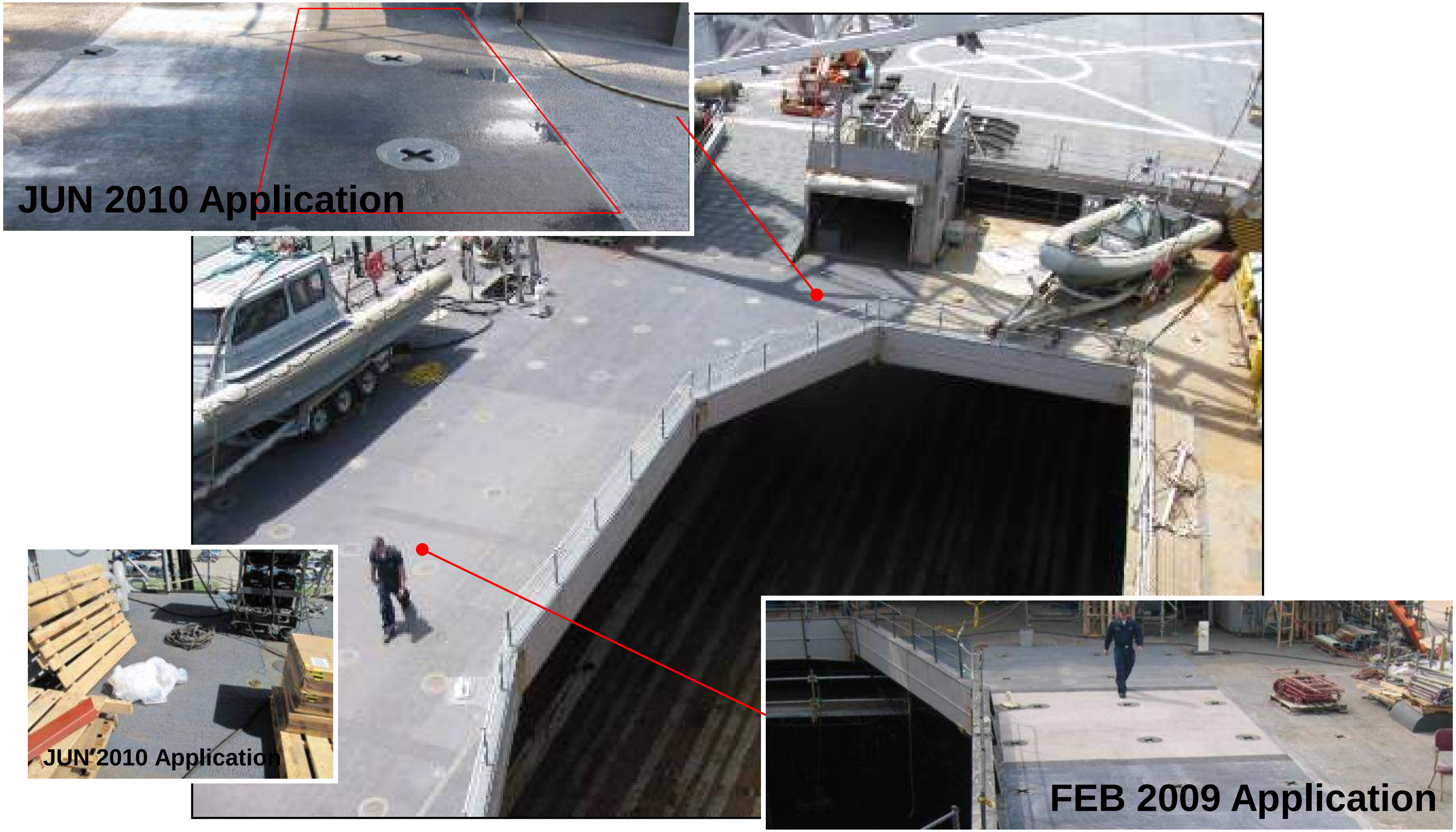
Extreme Temperature (JSF) Nonskid





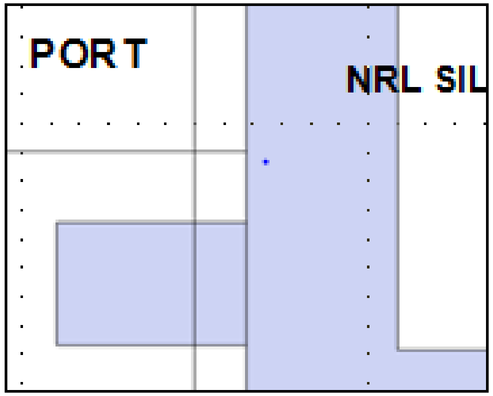
Cored Aluminum Wire With Ceramic Powder
Applied By Twin Wire Arc Spray

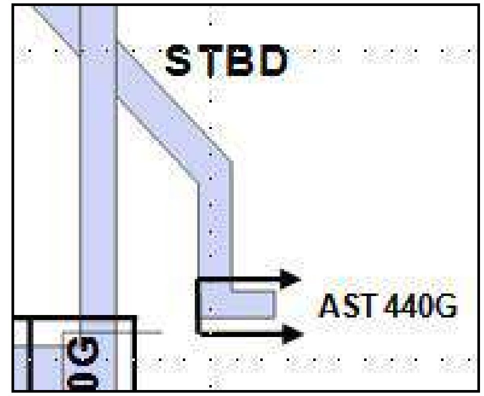
USS Whidbey Island Boat Deck and MOGAS – 2009



First application of thermal spray to high wear area of deck

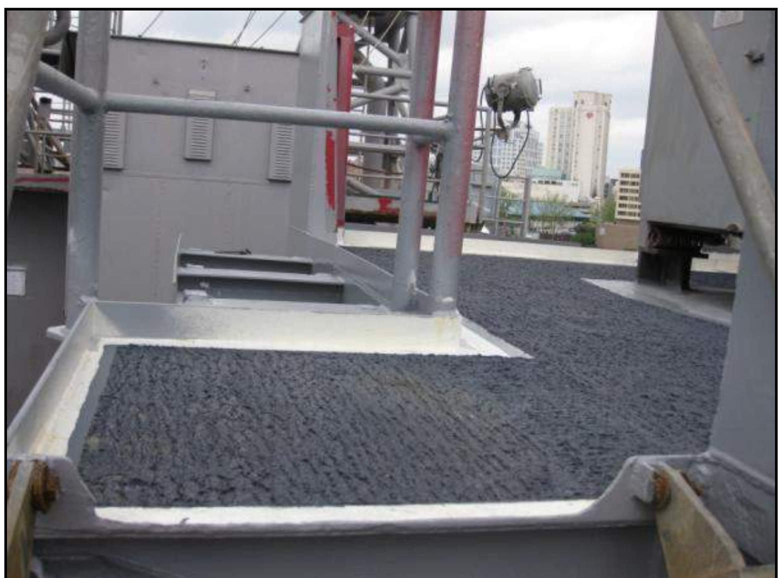
USS Ponce CIWS Foundation and 03 Aux Conn



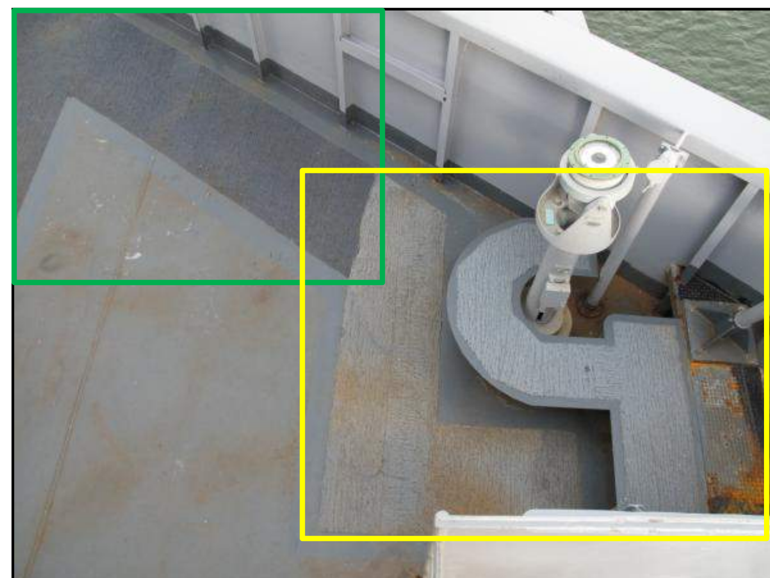


NRL Silxoane Rev 1

Conventional Nonskid, chalking after 5 months



CIWS Foundation – Initial Installation



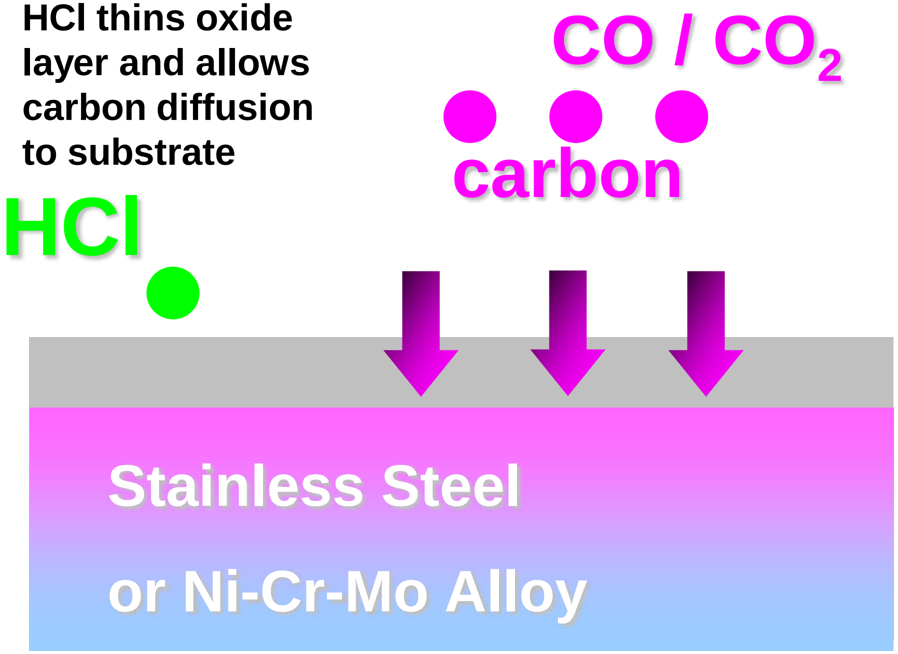
03 Aux Conn – 5 Month Follow-Up

NRL Polysiloxane outperforming conventional nonskid,

Corrosion Resistant Surface Treatment Process

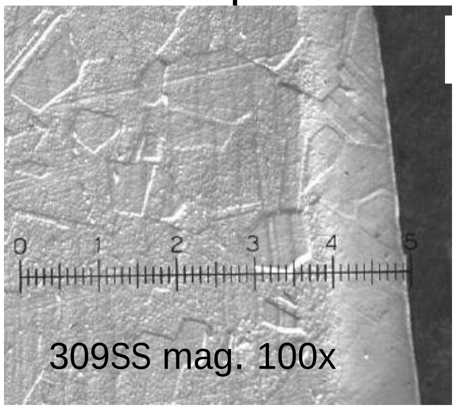
- Original grain structures retained with significant interstitial carbon
- **No precipitates or carbides** – carbon is interstitial with significant lattice expansion indicating residual compressive surface stress
- Interstitially carburized layer is referred to as “S-phase”

Activation via HCl thins oxide layer and allows carbon diffusion to substrate

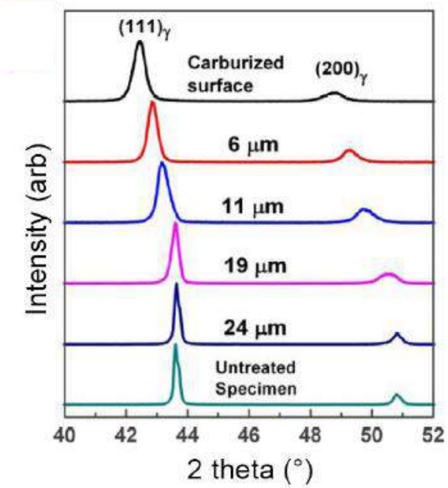


Cr_2O_3

Air-formed oxide layer blocks carbon diffusion at low temperature
Inhibits carburization



XRD on 316SS



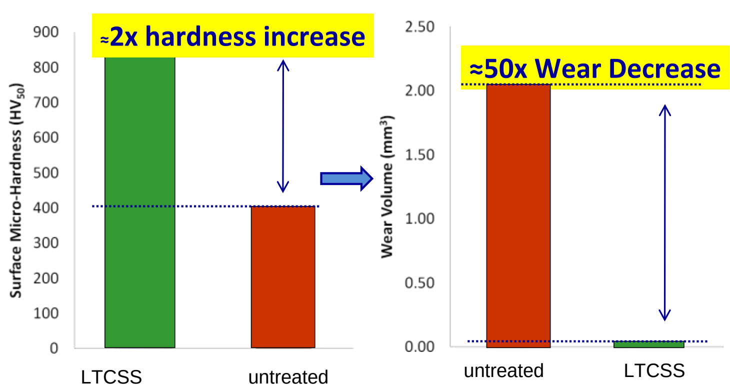
Ref: G. M. Michal, et al., Acta Materialia 54, 1597 (2006).

Corrosion Resistant Surface Treatment

- A cavitation and corrosion resistant treatment process based on interstitial surface alloying technologies for application to waterjet impellers and fasteners
  - ➢ Increased resistance to corrosion by 4x
  - ➢ Improved cavitation resistance by 3X
  - ➢ Increased resistance to corrosion fatigue by 10x
  - ➢ Increased resistance to galling 10x
  - ➢ Increased resistance to wear by 3x
  - ➢ Increase in service life by 3X

- Deliverable will be CID (Commercial Item Description) for corrosion and cavitation resistant components

Hardness and Wear: 13-8 SS



Fins on untreated 316SS impeller worn away in 4 months.
Fins on Treated 316SS impeller maintained dimensions.

Corrosion Resistant Surface Treatment Summary

- **CRST offers an existing industrial process with applicability to a wide range of conventional materials.**
- **Other solutions require new or advanced materials or whole sale redesign of the system, both of which are costly and significantly acquisition.**
- **CRST is the only technology which has shown a substantial improvement in cavitation/erosion resistance for the existing design and alloys.**

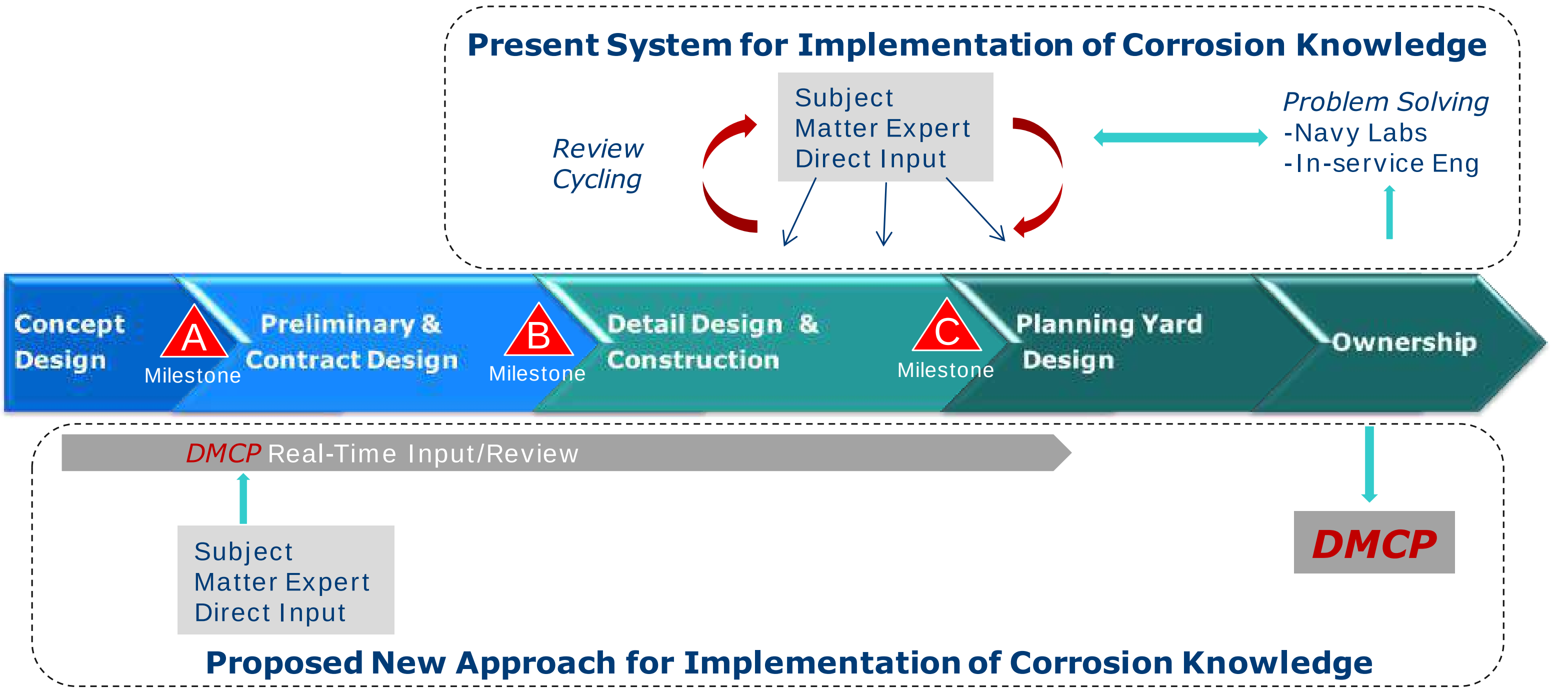
Provides:

- **Significant reduction in maintenance**
- **Decrease lifecycle cost**
- **Increased reliability and asset availability**
- **Decrease fuel consumption.**

Design Modules for Corrosion Prevention

Moving Corrosion Expertise Earlier into the Acquisition Cycle

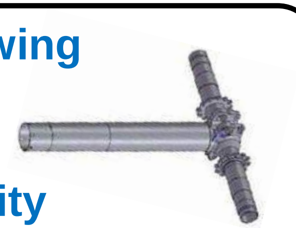
- Navy-wide corrosion issues share a common problem
  - Insufficient consideration for corrosion prevention in the acquisition cycle prior to Milestone B and C
- No technical solutions presently exist to address this challenge
- This EC product will move corrosion prevention inputs forward in the design process, increasing the efficiency and effectiveness of the corrosion review process for new components and systems
- The developed product will provide a future transition path for current S&T in corrosion mechanistic studies and related computational modeling being developed by ONR Code 333



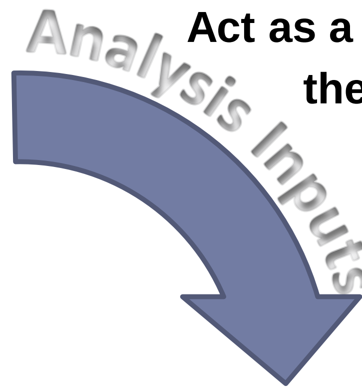
Design Modules for Corrosion Prevention

Interaction with DMCP Module:

System/Component Drawing
- **Geometry**
- **Materials & Coatings**
- **Component Connectivity**



Component Usage
- **Environment**
- **Function**
- **Maintainability**



Act as a tool native to the CAD system environment

Assimilate results into overall corrosion risk score

Corrosion Analysis Results
- **Corrosion Risks**
- **Life Prediction**
- **Design Revisions**

Acknowledgements

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- NRL would also like to recognize the continued partnership with NSWCCD which has substantially contributed to these programs.