



# S&T Efforts for Navy Corrosion Control

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Center for Corrosion Science & Engineering

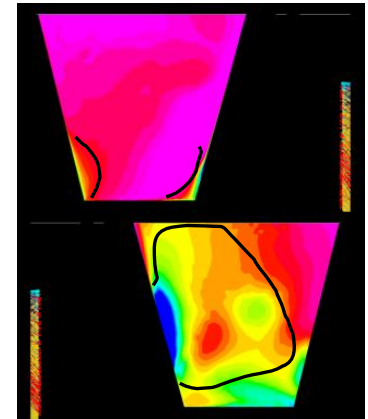
NRL Code 6130

| Report Documentation Page                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                    |                                     |                                                           | Form Approved<br>OMB No. 0704-0188                  |                                 |
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# Overview

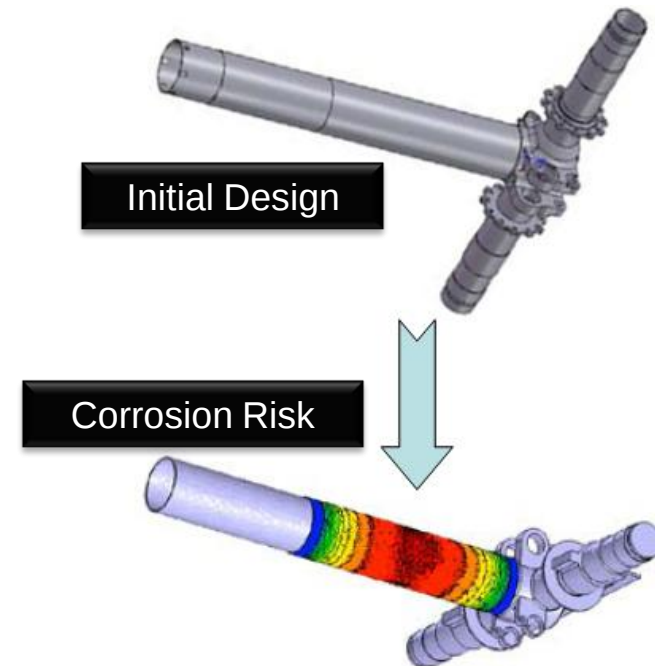
## ■ *Maintenance Reduction Technologies (FY08-FY12)*

- 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



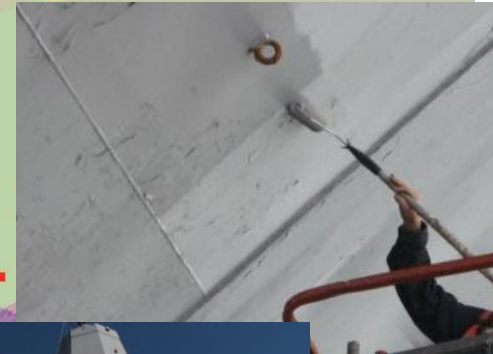
# Current Navy Topside Coatings

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**

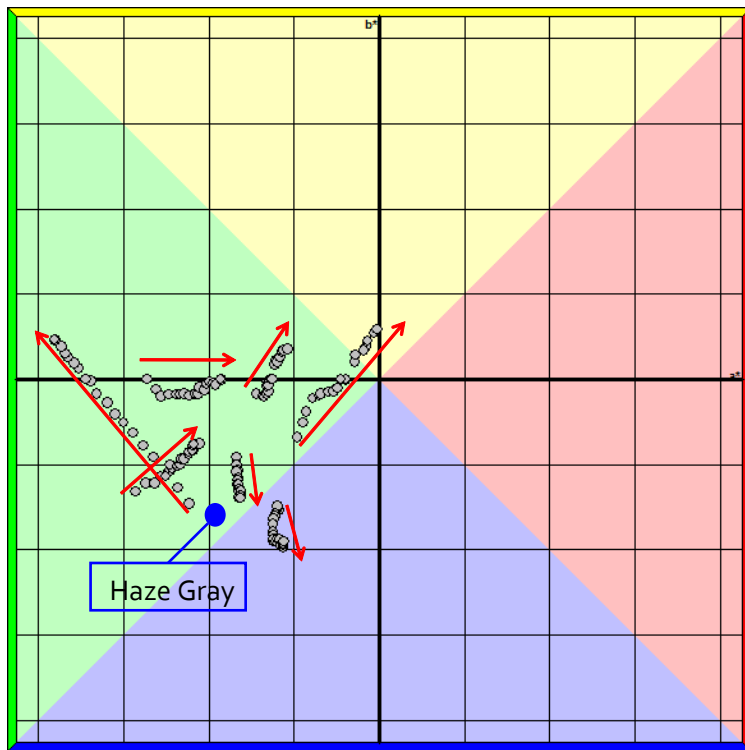
Poor Performance → Constant Overcoating



# Advanced Topside Coatings : Phase I Lab Testing

## Commercial Products

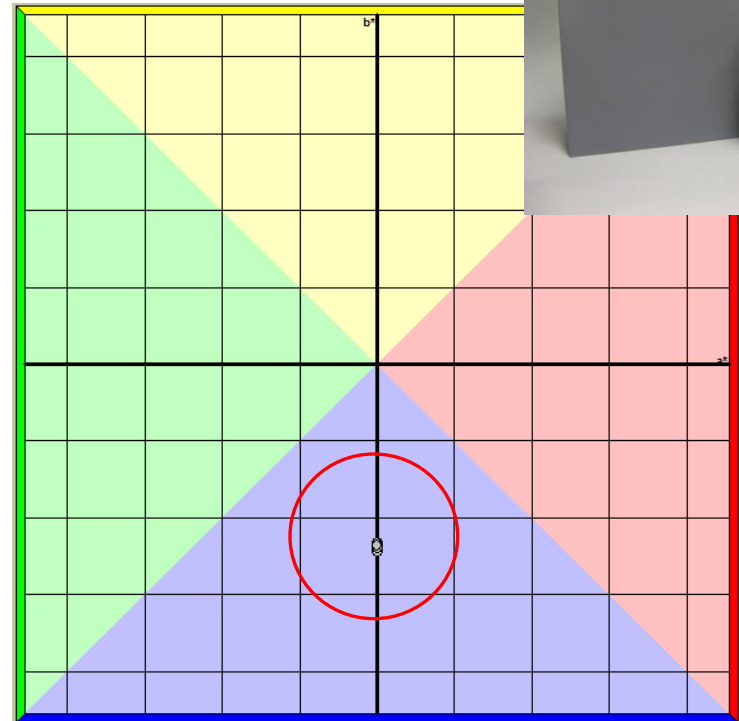
We 2000 HOURS **WOM**



**BEST DOWN SELECTED FOR RETEST AND SHIP DEMO**

## NRL Polysiloxane

- 2K system 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 1<sup>st</sup> 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*

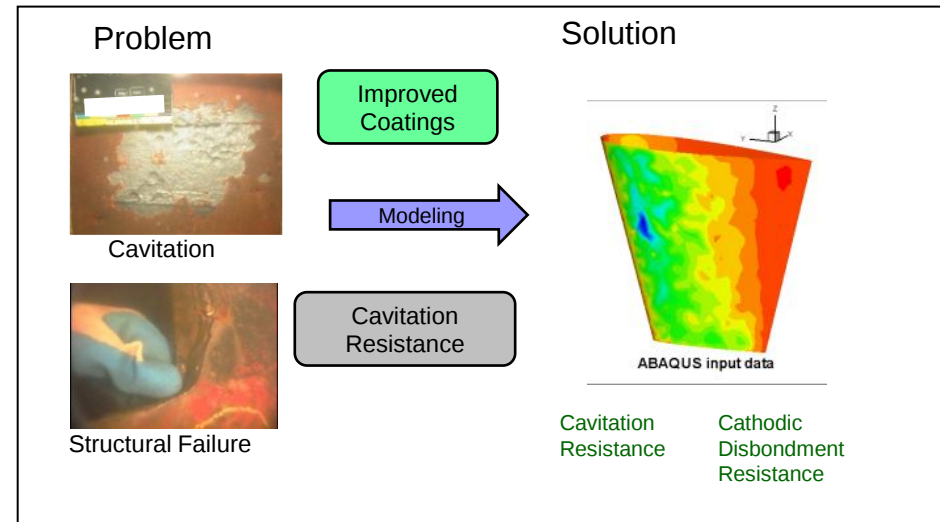
# Advanced Rudder Coatings

## ■ 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



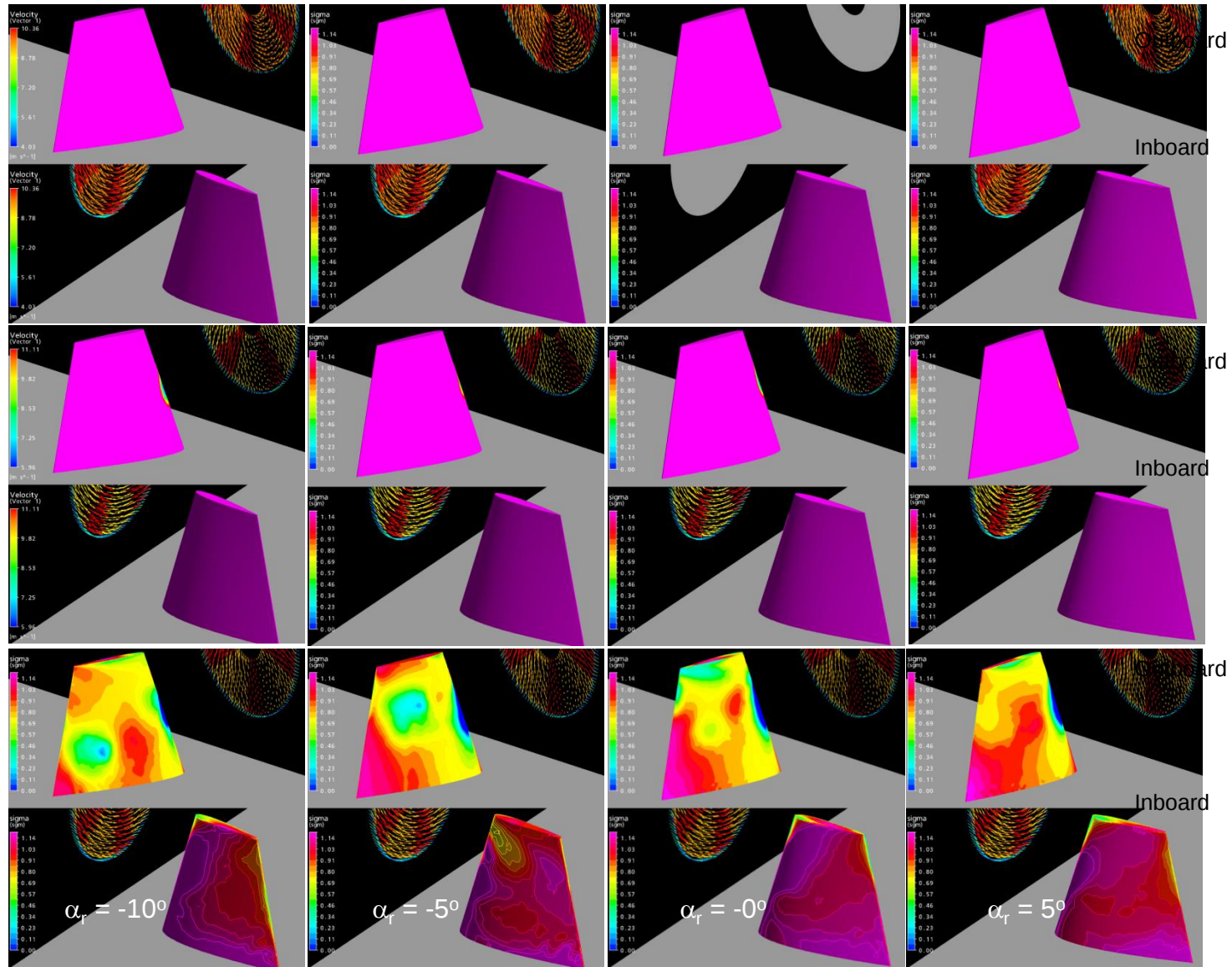
# Rudder Coatings: CFD

Cavitation Coefficient with Velocity and Angle of Attack

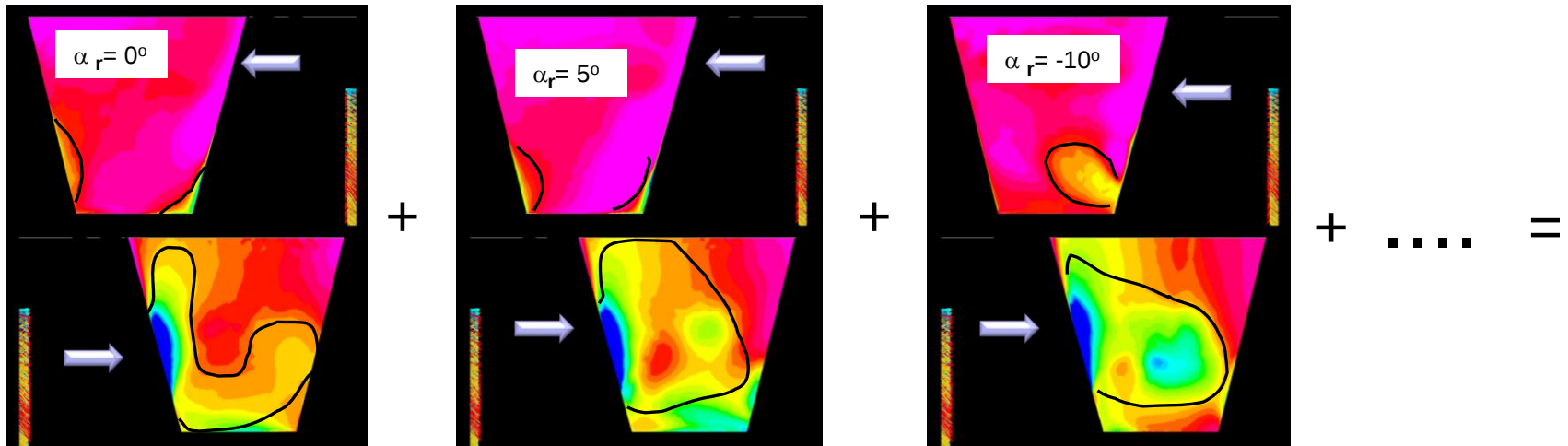
1/3 Speed  
Velocity (No  
cavitation)

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

Standard Speed  
Velocity  
(Cavitation for all  
angles)

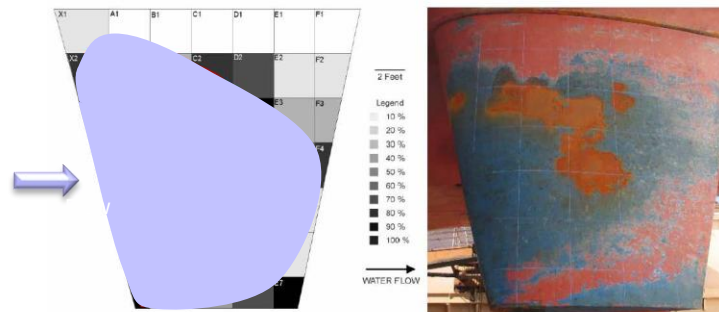


# Development of Cavitation Initiation Area



$\alpha_r$  = rudder angle

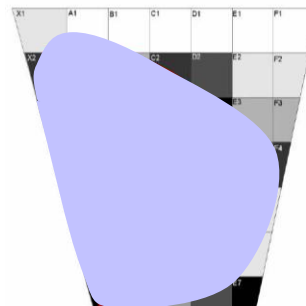
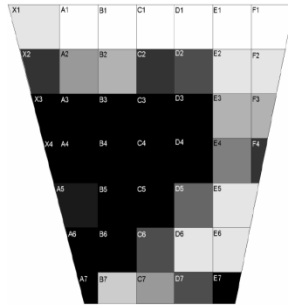
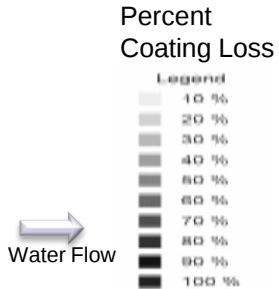
DDG 83 USS HOWARD  
Port Rudder, Outboard Face  
Anti-Fouling Coating Loss



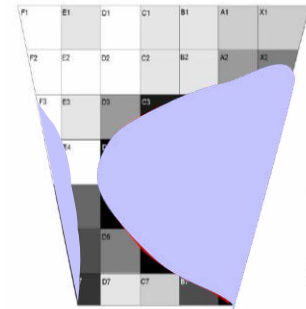
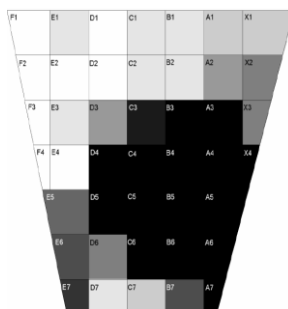
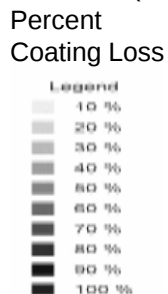
Total Surface Area: 152 ft<sup>2</sup>  
Total AF Lost: 86.9 ft<sup>2</sup>  
Total Percent Exposed: 57.0 %

# Sheet Cavitation Regions Determined From CFD

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



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



← Water Flow

- 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

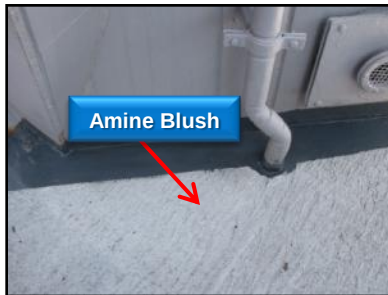
### ***PLANNING FOR 2-3 DEMONSTRATIONS IN FY11:***

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

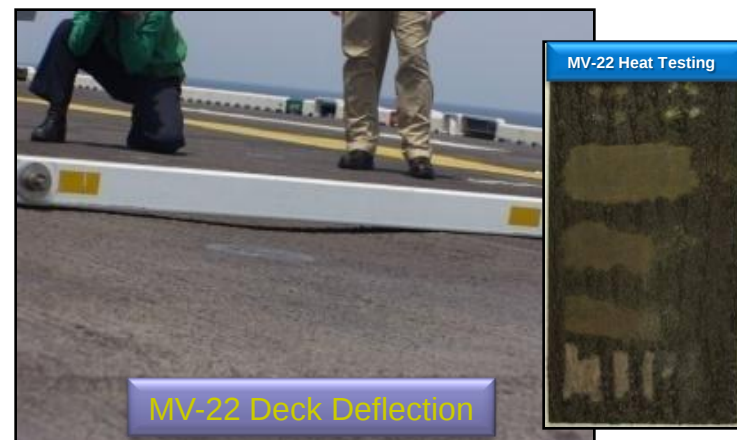
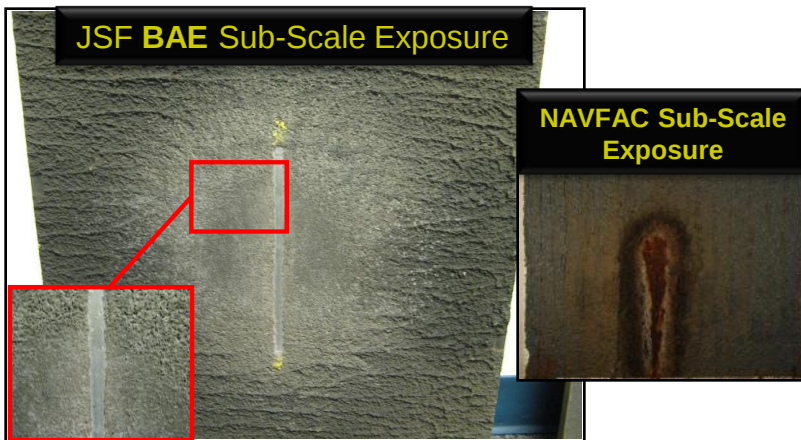
# High Performance Non Skid

## 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)



Novolac Epoxy



NRL HD1  
(Rolled)



NRL HD1  
(Sprayed)



Thermion

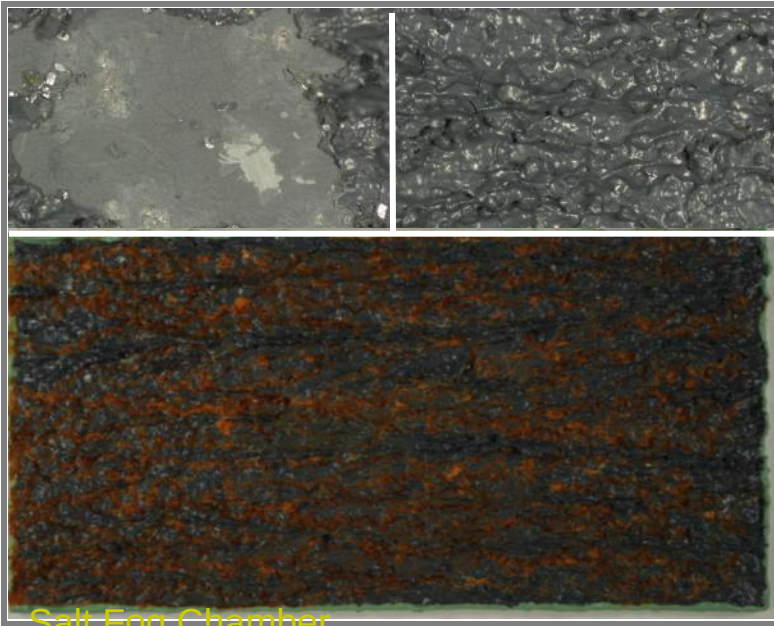


Hybrid Thermal  
Spray



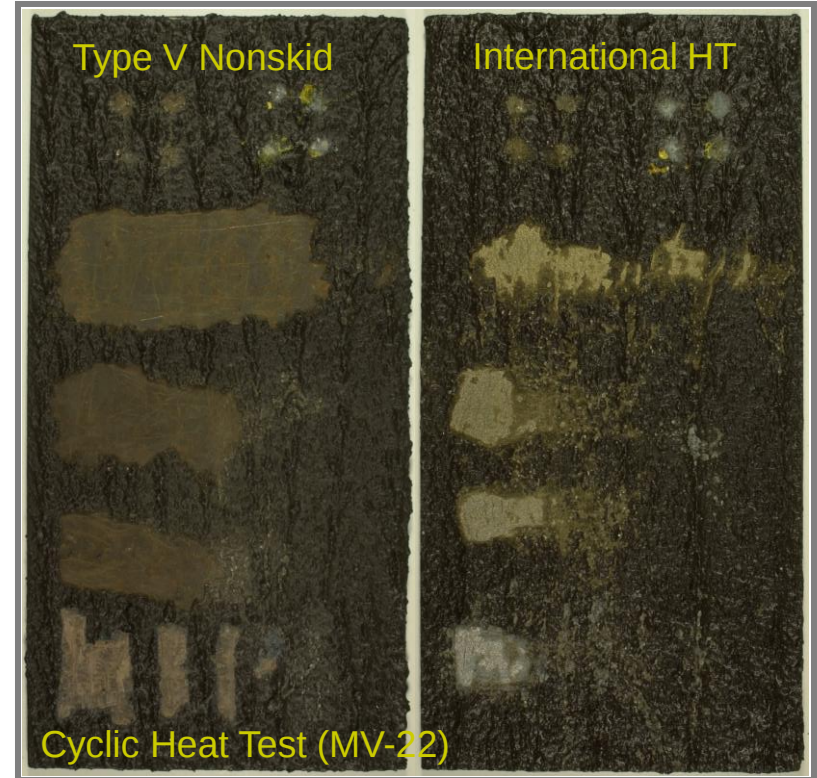
Cementitious

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



Salt Fog Chamber

Polysiloxane Nonskid and Primer  
Applied by Napless Roller

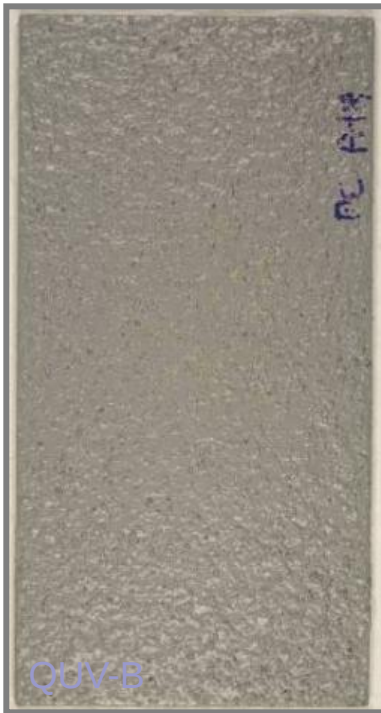


Cyclic Heat Test (MV-22)

Silicone/Epoxy Hybrid Coating  
Applied by Napless Roller

# Extreme Durability Nonskid Coatings

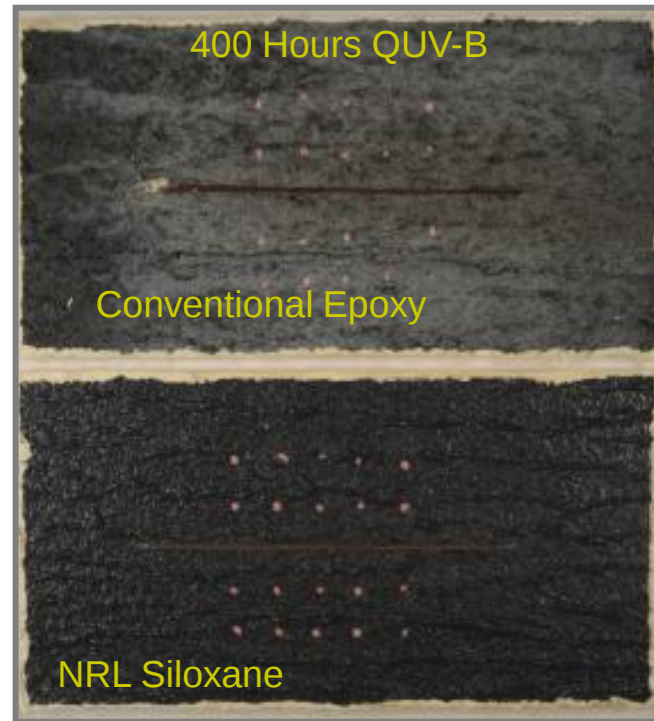
## Skid Pro



Cementitious polymer w/aggregate  
Applied By Spray Equipment

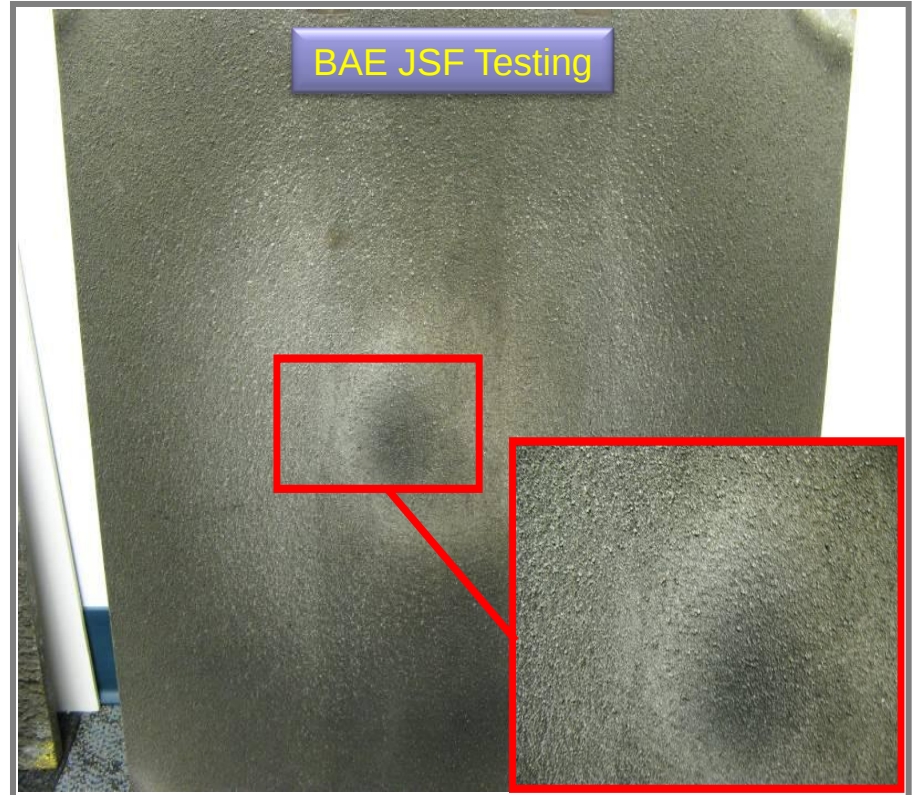
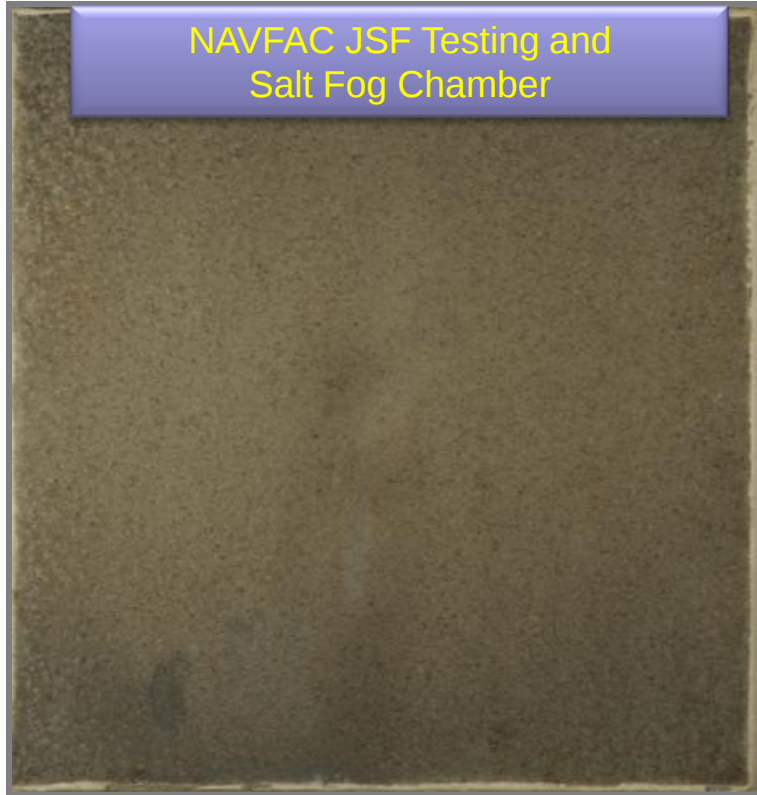


## NRL Siloxane (Bottom)



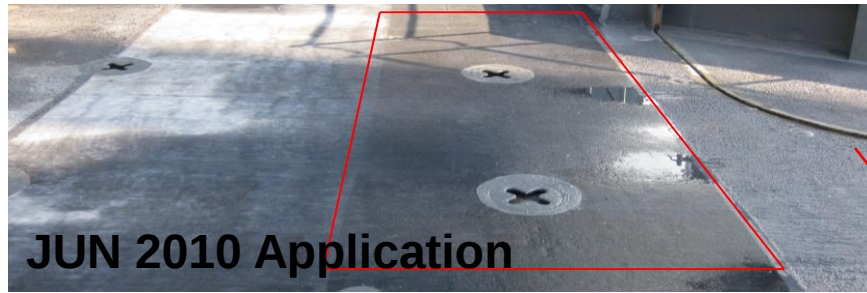
Polysiloxane Base Resin  
Applied By Napless Roller

# Extreme Temperature (JSF) Nonskid



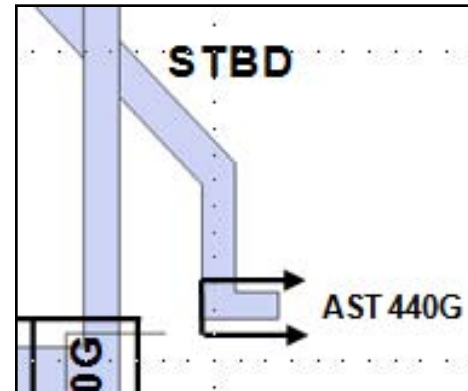
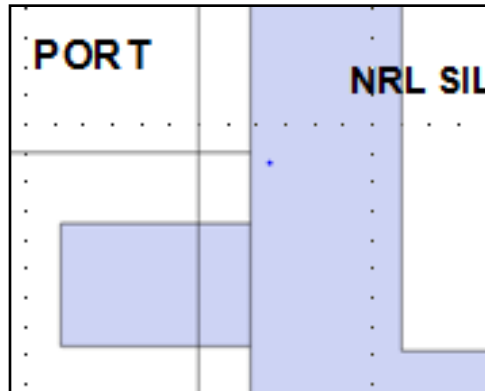
Cored Aluminum Wire With Ceramic Powder  
Applied By Twin Wire Arc Spray

# *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



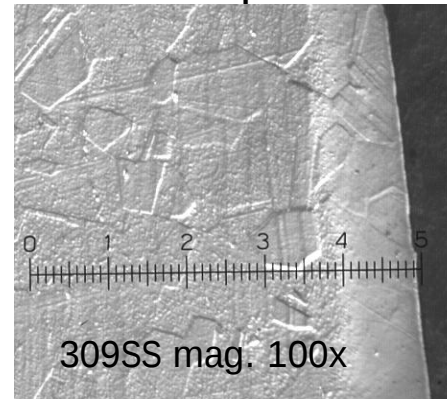
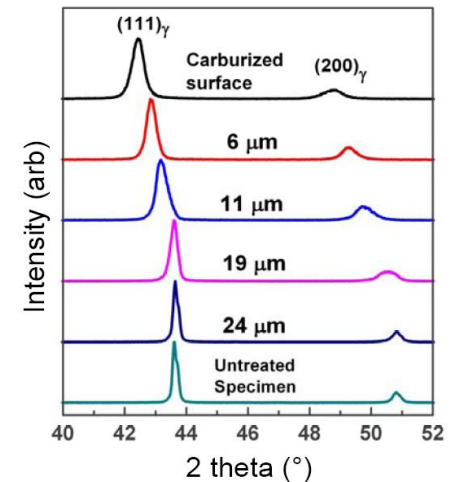
03 Aux Conn – 5 Month Follow-Up

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”

XRD on 316SS



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

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

HCl

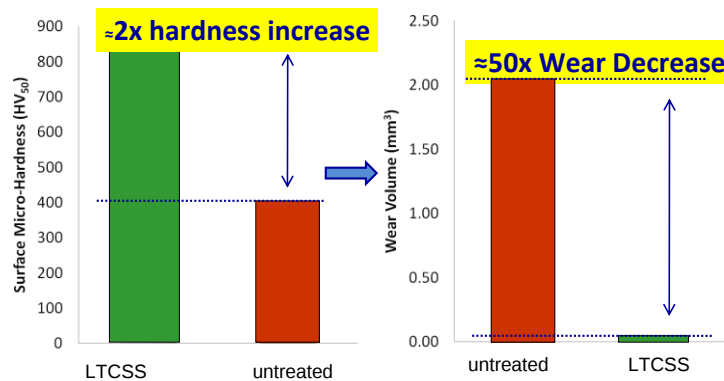
CO / CO<sub>2</sub>  
carbon

Stainless Steel  
or Ni-Cr-Mo Alloy

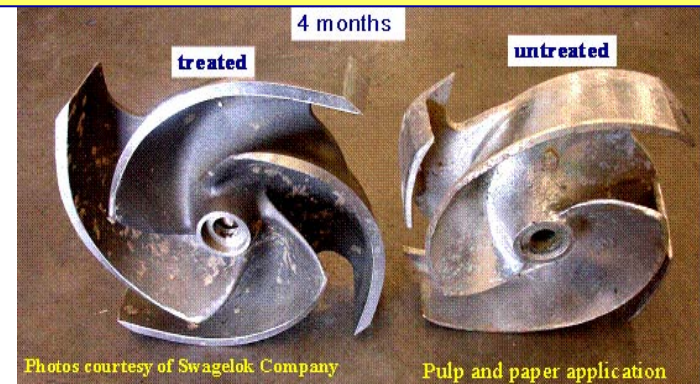
# Corrosion Resistant Surface Treatment

- 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:

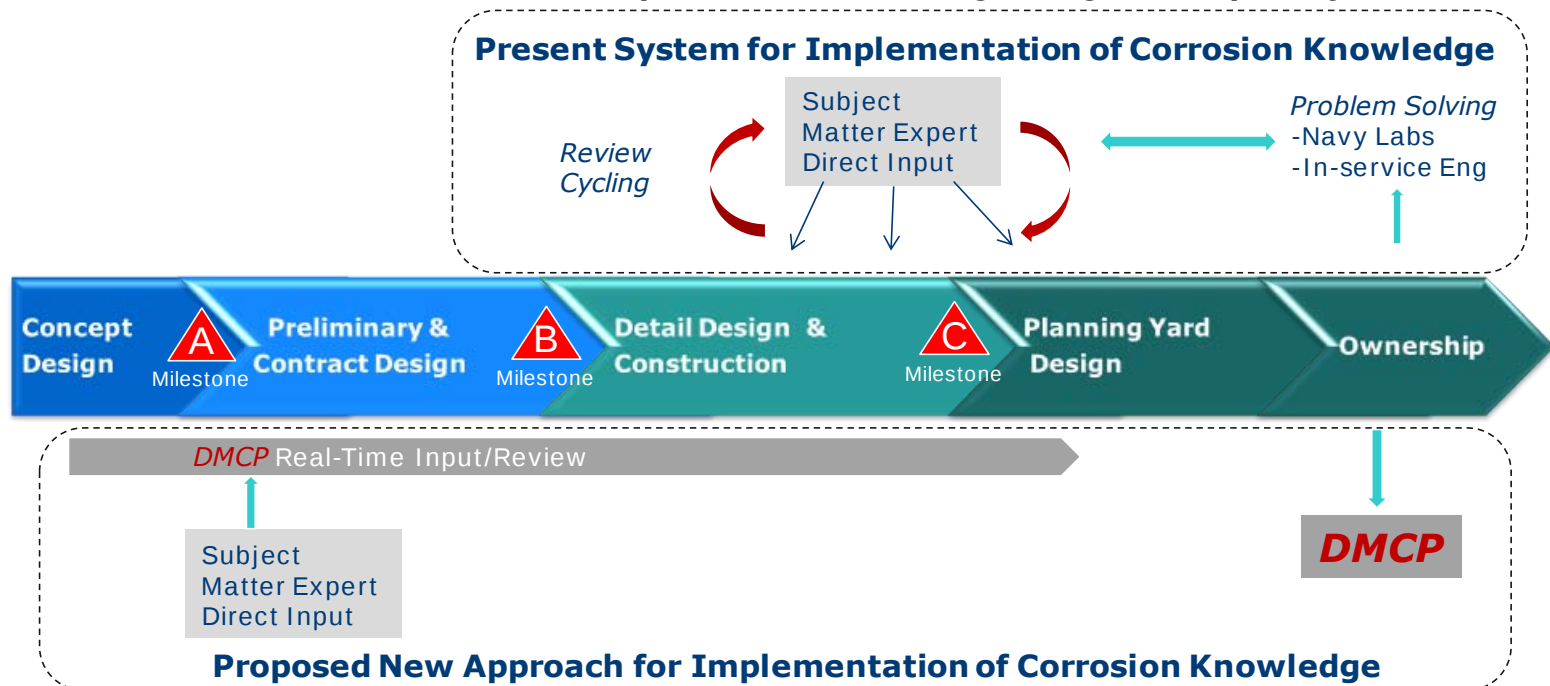
- Significant reduction in maintenance
- Decrease lifecycle cost
- Increased reliability and asset availability
- Decrease fuel consumption.



# 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

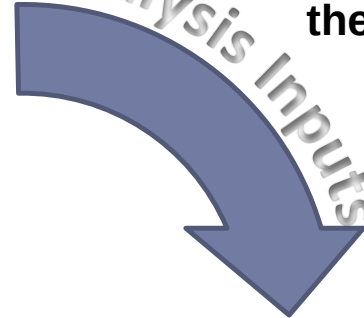


### Corrosion Analysis Results

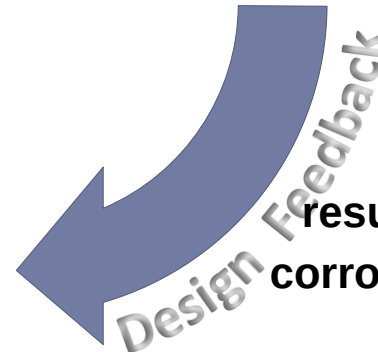
- Corrosion Risks
- Life Prediction
- Design Revisions



Act as a tool native to  
the CAD system  
environment



Assimilate  
results into overall  
corrosion risk score





# Acknowledgements

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