Environmentally-Preferable Launch Coatings

NASA Corrosion Technology Laboratory
&
NASA Technology Evaluation for Environmental Risk Mitigation

Environmentally-Preferable Launch Coatings

Outline

- **Background**
- **NASA-STD-5008B**
- **Risk**
  - **Environmental Concerns**
- **Objective**
- **Coating Selection**
- **Testing**
  - **Critical Requirement Tests**
  - **Performance Tests**
- **Collaboration**
- **Summary**

Environmentally-Preferable Launch Coatings

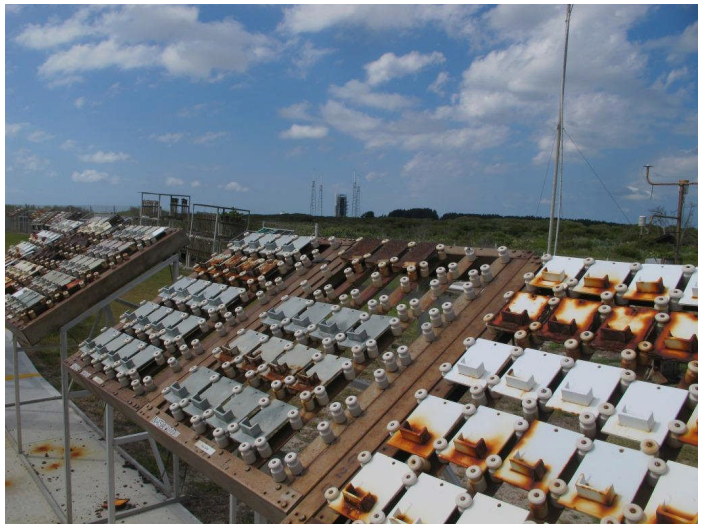
Background

- NASA is responsible for a number of facilities and structures with metallic structural and nonstructural components in a highly corrosive environment.
- Metals require periodic maintenance activity to guard against the insidious effects of corrosion and thus ensure that structures meet or exceed design or performance life.
- The deleterious effects of corrosion result in steep costs, asset downtime affecting mission readiness, and safety risks to personnel.
- It is vital to reduce corrosion costs and risks in a sustainable manner.

Environmentally-Preferable Launch Coatings

Background

- Maintenance at KSC is governed by NASA-STD-5008B (*Protective Coating of Carbon Steel, Stainless Steel, and Aluminum on Launch Structures, Facilities, and Ground Support Equipment*) which establishes practices for the protective coating of launch facilities used by or for NASA programs and projects.
- The Standard is also recommended guidance for all NASA Centers and is for the design of non-flight hardware used to support the operations of receiving, transportation, handling, assembly, inspection, test, checkout, service, and launch of space vehicles and payloads at NASA launch, landing, or retrieval sites.



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NASA-STD-5008B, Important Notes

- Original Signed By: Michael G. Ryschkewitsch; NASA Chief Engineer = 03/18/2011
- This Standard is approved for use by NASA Headquarters and NASA Centers, including Component Facilities and Technical and Service Support Centers.
- This Standard was developed to ensure the inclusion of essential criteria in the coating of ground support equipment (GSE) and facilities used by or for NASA.
- This Standard is for the design of nonflight hardware used to support the operations of receiving, transportation, handling, assembly, inspection, test, checkout, service, and launch of space vehicles and payloads at NASA launch, landing, or retrieval sites.
- To arrange for product testing and the testing criteria, manufacturers must contact the Engineering Directorate, NASA, John F. Kennedy Space (KSC) Center, FL 32899 or contact the Corrosion Technology Laboratory at http://corrosion.ksc.nasa.gov.

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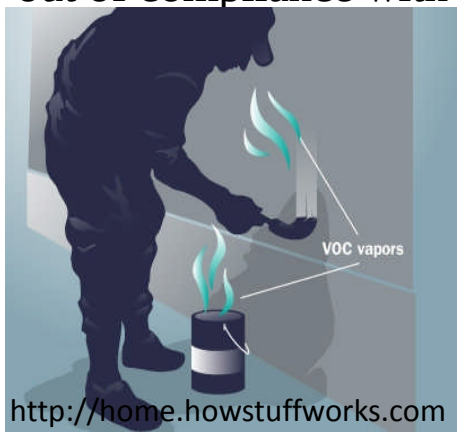
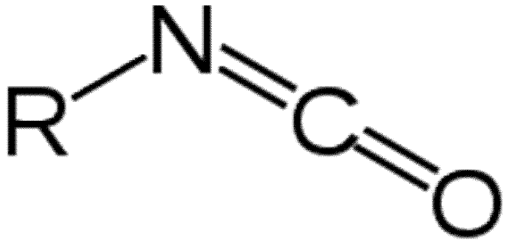
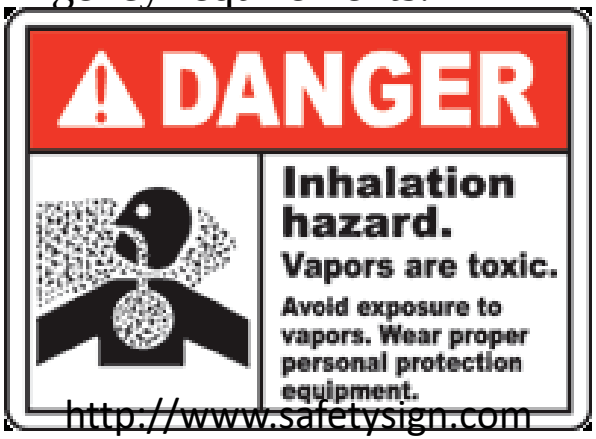
Risk

- **Potential Obsolescence and Additional Management Costs for HAPs, VOCs, and isocyanates:** Due to the regulations and restrictions on the use of HAPs , VOCs and isocyanates in coatings and preventative compounds containing these materials it is possible that materials containing VOCs, HAPS and isocyanates could become unavailable and that there will be significant and potentially increasing costs associated with the handling and disposal of hazardous materials and the management of VOC, HAP and isocyanate emissions.
- **Potential Human Exposures and Non-Compliance for HAPS, VOCs and isocyanates:** Due to the toxicity of VOCs, HAPs, and isocyanates used in NASA operations, and the restrictions on VOC content is possible that there will be occupational or public exposures or that NASA Centers could be out of compliance with Federal, State and local regulations and Agency requirements.



http://home.howstuffworks.com





http://www.safetysign.com

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Volatile Organic Compound (VOC) Levels

NASA-STD-5008B includes an “Approved Products List” (APL) of coatings that have very high volatile organic compound (VOC) levels which are no longer compliant with current environmental regulations.

- Currently the APL is divided into two categories:
  - Materials With Greater Than 400 Grams/Liter VOC
  - Materials With Less Than 400 Grams/Liter VOC

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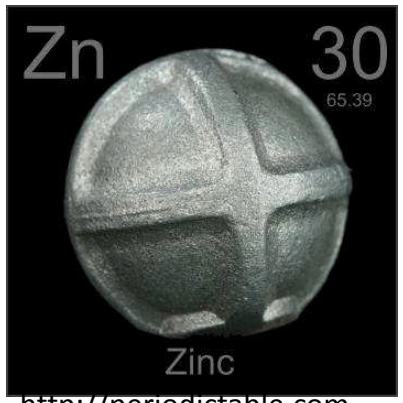
Inorganic Zinc (IOZ) Regulation - KSC

- Waste Inorganic Zinc (IOZ) paint and waste materials that have contacted IOZ paint are considered a hazardous waste due to the constituents in the paint.
- It is a regulatory violation to allow unused or leftover IOZ paint to open air dry at KSC.
  - When placed in a sealed container, IOZ paint can produce hydrogen and other gases from chemical reactions that occur during the curing process. The gas production builds pressure in the container and can cause the container to bulge and/or rupture thus creating a safety hazard.
  - Original product containers must then be placed into a larger closed drum or container that meets hazardous waste storage requirements and prevents any possible release to the environment the larger closed drum or container must have a 5 psi pressure relief vent to avoid potential safety hazards



http://periodictable.com


http://www.firerescue1.com

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Inorganic Zinc (IOZ) Considerations

Per NASA-STD-5008B, section 4.5.1 Protection of Carbon Steel:
a. Carbon steel surfaces shall be protected from atmospheric corrosion through the application of zinc coatings (inorganic zinc coating and/or hot-dip galvanizing and/or metallizing) as defined herein.

Application Considerations

- Inorganic Zinc coatings require moisture cure:
  - Carbozinc 11 - Where the relative humidity is below 40%, allow an initial 2-hour ambient cure. Follow 2 hour cure with water misting or steam to keep the coated surface wet for a minimum of 8 hours and until the coated surface achieves a "2H" pencil hardness per ASTM D3363.
  - Sherwin Williams Zinc Clad II Plus - Water misting may be required at humidity levels below 50%



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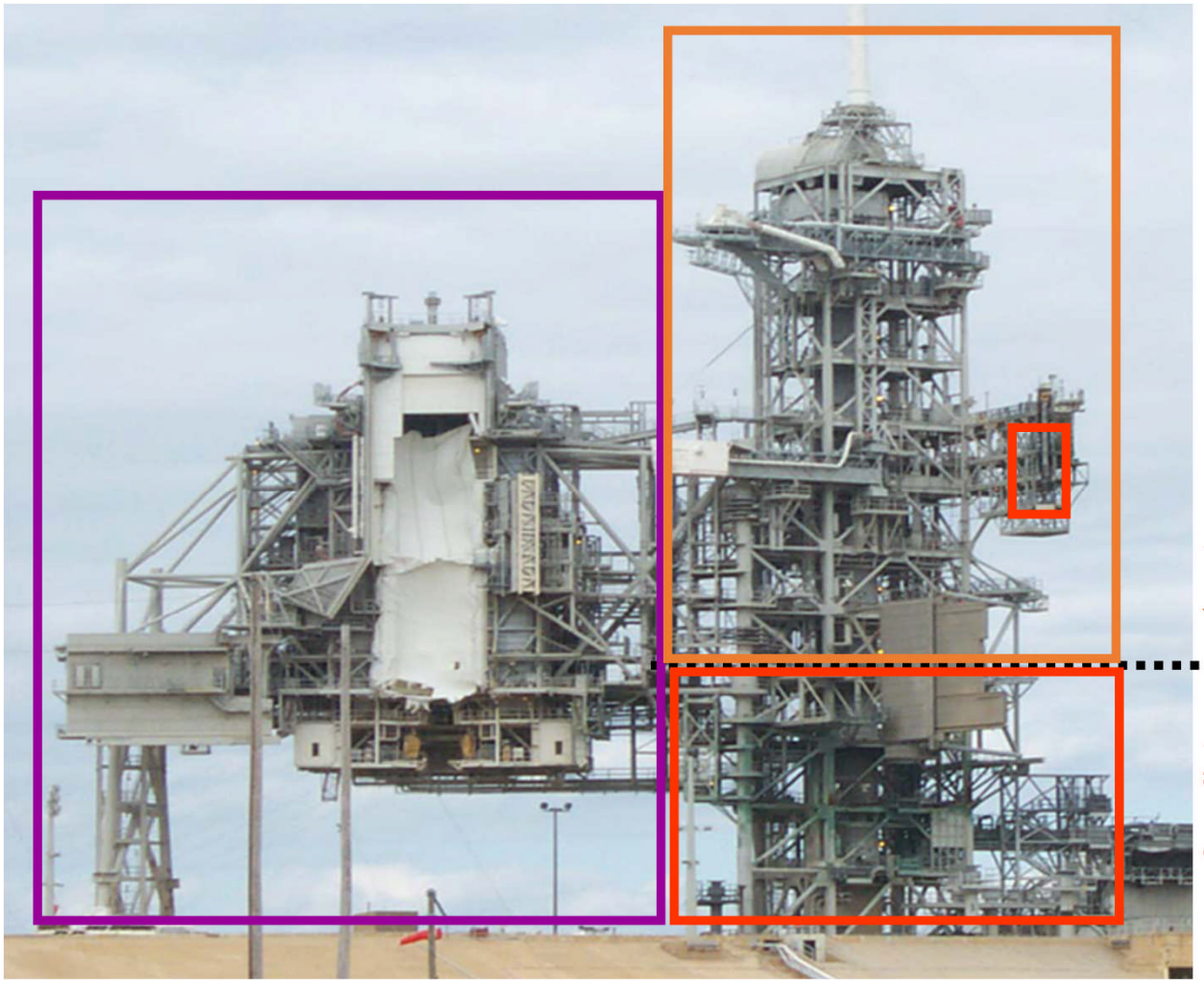
Objective

- The primary objective of this effort is to demonstrate and validate environmentally-preferable alternatives in accordance with NASA-STD-5008B which can then be added to the APL used as a specification in contracts by NASA.
- The focus of the project is corrosion resistance and survivability with the goal to reduce the amount of maintenance required to preserve the performance of launch facilities while reducing mission risk. The project compares coating performance of the selected alternatives to existing coating systems or standards.

Environmentally-Preferable Launch Coatings

Launch Complex 39 Zones of Exposure



Zone 3: Surfaces, other than those located in Zones 1 or 2, that receive acid deposition from solid rocket booster exhaust products.
Surfaces that are exposed to other types of chemical contamination (e.g., cooling towers, diesel exhaust stacks, acidic industrial environments, and water treatment facilities).
Zone 4: Surfaces not located in the launch environment but located in a neutral pH corrosive marine industrial environment or other chloride containing environments.
Surfaces located in neutral pH exterior environments in any geographical area.
Surfaces located in indoor environments that are not air-conditioned. {VAB}

Zone 2: Surfaces that receive elevated temperatures and acid deposition from solid rocket booster exhaust with no exhaust impingement.

Zone 1: Surfaces that are directly impinged on by solid rocket booster (SRB) engine exhaust.
Surfaces that are indirectly impinged on by SRB exhaust.

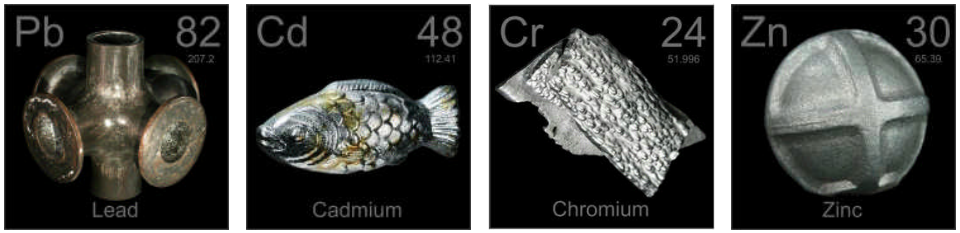
Environmentally-Preferable Launch Coatings

Coating Selection

- 44 coatings were reviewed for this effort
- A coatings database is being developed in order to capture all of the information collected

Coating Selection Considerations

- Commercial Availability
- Technical Feasibility
- Volatile Organic Compound (VOC) Content <200 g/L
- Hazardous Air Pollutants (HAPs) Content
- Other Hazardous Constituents (RCRA, EPCRA, and CERCLA)
- Isocyanates
  - OSHA requires employers to provide a work environment that minimizes or eliminates exposure to isocyanate-containing products. Isocyanates are classified as potential human carcinogens and are known to cause cancer in animals. The main effects of overexposure are occupational asthma and other lung problems, as well as irritation of the eyes, nose, throat, and skin.
- Heavy Metal Content
  - Lead Free
  - Cadmium Free
  - Chromium Free
  - Zinc



Environmentally-Preferable Launch Coatings

Phase 1 Testing

Phase 1 Testing CRITICAL Requirements for Environmentally-preferable Coatings				
Test	**Test Specimen**	**Acceptance Criteria**	**Requirement**	**Test Methodology References**
Pot Life	Mixed Coating System	Based on Applicator Evaluation: Equal to or better than control coating	NASA-STD-5008B	None
Ease of Application	Coupon	Based on Applicator Evaluation: Smooth coat, with acceptable appearance, no runs, bubbles or sags; Ability to cover the properly prepared/primed substrate with a single coat (one-coat hiding ability); Measure Dry Film Thickness.	NASA-STD-5008B	SSPC-PA-2
Surface Appearance	Coupon	Based on Applicator Evaluation: No streaks, blistering, voids, air bubbles, cratering, lifting, blushing, or other surface defects/irregularities; No micro-cracks observable at 10X magnification	NASA-STD-5008B	ASTM D 523 ASTM D 2244
Atmospheric Exposure	Coupon	Attain a rating of not less than 8 in accordance with ASTM D610; 18 months initial acceptance, 5 years for final acceptance	NASA-STD-5008B	ASTM D 610, ASTM D 714

- These tests are considered critical in order to evaluate the ease of use and application of the coatings, as well as determine how well the coating protects carbon steel against corrosion in a harsh marine environment.

- The coatings ability to stand up to acid deposition is not currently being evaluated, however, this testing should be considered for inclusion in future revisions of NASA-STD-5008B.

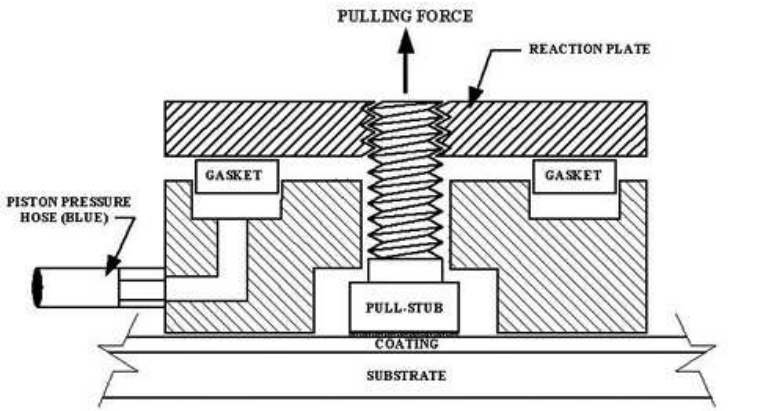
Environmentally-Preferable Launch Coatings

Phase 1 Testing

Phase 1 Testing Requirements for Environmentally-preferable Coatings				
Test	**Test Specimen**	**Acceptance Criteria**	**Requirement**	**Test Methodology References**
Primer Heat Adhesion	Coupon	No loss of adhesion after heating @ 400 °C (750 °F) for 24 hours	NASA-STD-5008B	ASTM D 4541
Atmospheric Exposure	Coupon	Retain gloss and color on prolonged outdoor exposure	NASA-STD-5008B	ASTM D 523

- The primer heat adhesion requirement is directly tied to NASA-STD-5008B, section 4.5.1 Protection of Carbon Steel; which requires that carbon steel surfaces shall be protected from atmospheric corrosion through the application of zinc coatings. Coatings that do not contain inorganic zinc are not expected to pass this requirement.

- Color and Gloss readings are required over the duration of testing, however they are not considered a critical criteria unless the coatings are grossly underperforming, with obvious fading and chalking observed.



CROSS-SECTIONAL SCHEMATIC OF SELF-ALIGNING PISTON WITH PULL-STUB

Environmentally-Preferable Launch Coatings

Coating Systems Selected for Phase 1 Initial Coatings Testing

Manufacturer	Type	Primer	Intermediate	Topcoat
A&E Group	Isocyanate Free	N/A	N/A	Alocit 28.15 Standard Grade Epoxy Coating Primer/Finish
A&E Group	Isocyanate Free	Alocit 28.14 Epoxy Coating-Zinc Primer	N/A	Alocit 28.15 Standard Grade Epoxy Coating Primer/Finish
Carboline	Isocyanate Free	Carbozinc 11 WB	Carbotherm 3300	Carbocyrlic 3359
Carboline	Zinc Free	Carbomastic 615	Carboguard 893	Carbothane 134 MC
Polyset	Isocyanate Free	Ply-Zinc WB 18	N/A	Ply-Guard ME
Polyset	Isocyanate & Zinc Free	N/A	N/A	Ply-Guard ME
Pratt & Lambert	Isocyanate & Zinc Free	Universal HP Acrylic Primer Z6631	N/A	Acrylic Waterborne DTM Z6841
Shield Products	Isocyanate & Zinc Free	SKU40003	N/A	SKU20059VC
Tesla	Isocyanate Free Reduced Zinc	TESLAN ZN Primer (Low VOC)	N/A	TESLAN Low VOC Urethane Topcoat (XUR-12041)
EonCoat	Isocyanate & Zinc Free	N/A	N/A	EonCoat
Carboline	Zinc Free	Carbomastic 615 with uCapsules	Carboguard 893	Carbothane 134MC
Ameron	**Baseline**	Dimetcote 9H	Amerlock 400	Amercoat 450H

Environmentally-Preferable Launch Coatings

Phase 1 CRITICAL Testing Results as Compared to the Baseline System										
Manufacturer	**Type**	**Primer**	**Intermediate**	**Topcoat**	**Pot Life**	**Ease of Application**	**Surface Appearance**	**Atmospheric Exposure Test**		
								Corrosion	**Blistering**	**Scribe**
A&E Group	Isocyanate Free	N/A	N/A	Alocit 28.15 Standard Grade Epoxy Coating Primer/Finish	FAIL[1]	Removed from testing				
A&E Group	Isocyanate Free	Alocit 28.14 Epoxy Coating-Zinc Primer	N/A	Alocit 28.15 Standard Grade Epoxy Coating Primer/Finish	FAIL[1]	FAIL	PASS	FAIL	FAIL	FAIL
Carboline	Isocyanate Free	Carbozinc 11 WB	Carbotherm 3300	Carbocyrlic 3359	PASS	PASS	PASS	Equal	Equal	Equal
Carboline	Zinc Free	Carbomastic 615	Carboguard 893	Carbothane 134 MC	PASS	PASS	PASS	FAIL	FAIL	FAIL
Polyset	Isocyanate Free	Ply-Zinc WB 18	N/A	Ply-Guard ME	PASS	PASS	PASS	PASS	Equal	Equal
Polyset	Isocyanate & Zinc Free	N/A	N/A	Ply-Guard ME	PASS	PASS	PASS	FAIL	FAIL	FAIL
Pratt & Lambert	Isocyanate & Zinc Free	Universal HP Acrylic Primer Z6631	N/A	Acrylic Waterborne DTM Z6841	PASS	PASS	PASS	FAIL	FAIL	FAIL
Shield Products	Isocyanate & Zinc Free	SKU40003	N/A	SKU20059VC	PASS	PASS	PASS	FAIL	FAIL	FAIL
Tesla	Isocyanate Free Reduced Zinc	TESLAN ZN Primer (Low VOC)	N/A	TESLAN Low VOC Urethane Topcoat (XUR-12041)	PASS	PASS	PASS	FAIL	FAIL	FAIL
EonCoat	Isocyanate & Zinc Free	N/A	N/A	EonCoat	PASS	PASS	PASS	PASS	Equal	Equal
Carboline	Zinc Free	Carbomastic 615 with uCapsules	Carboguard 893	Carbothane 134MC	FAIL[2]	FAIL	PASS	FAIL	FAIL	FAIL
FAIL[1] = The coatings heated up very quickly and catalyzation began before application could commence										
FAIL[2] = The coating was applied successfully using a Plas-Pak, Ratio-Pak® Industrial Spray Dispenser plural component system										

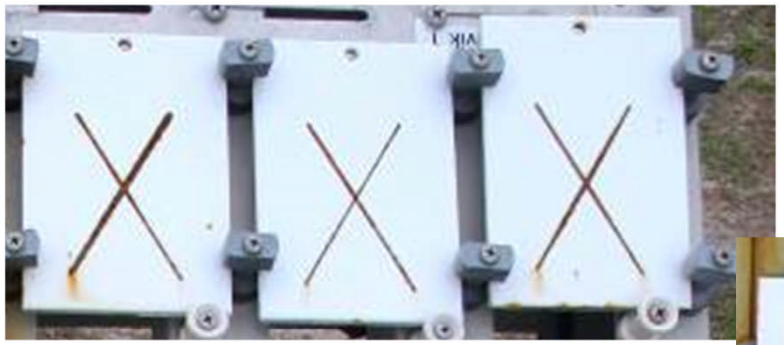
Environmentally-Preferable Launch Coatings

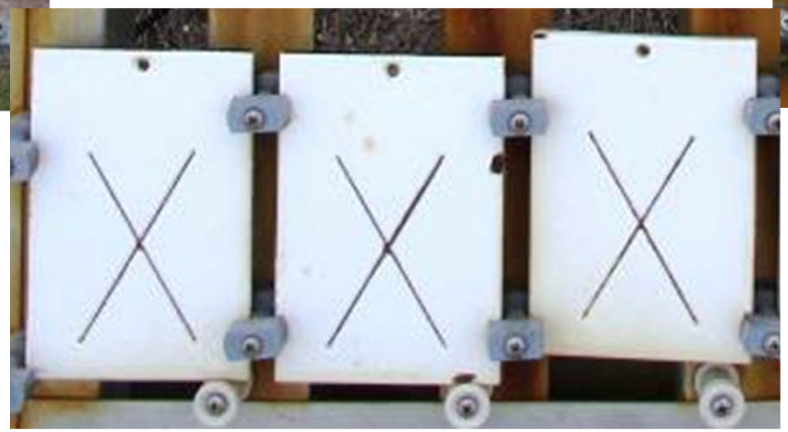
Phase 1 Testing Results as Compared to the Baseline System							
Manufacturer	**Type**	**Primer**	**Intermediate**	**Topcoat**	**Primer Heat Adhesion**	**Atmospheric Exposure Test**	
						Color	**Gloss**
A&E Group	Isocyanate Free	Alocit 28.14 Epoxy Coating-Zinc Primer	N/A	Alocit 28.15 Standard Grade Epoxy Coating Primer/Finish	FAIL	FAIL	FAIL
Carboline	Isocyanate Free	Carbozinc 11 WB	Carbotherm 3300	Carbocyrlic 3359	Equal	Equal	PASS
Carboline	Zinc Free	Carbomastic 615	Carboguard 893	Carbothane 134 MC	FAIL	FAIL	PASS
Polyset	Isocyanate Free	Ply-Zinc WB 18	N/A	Ply-Guard ME	Equal	Equal	FAIL
Polyset	Isocyanate & Zinc Free	N/A	N/A	Ply-Guard ME	FAIL	FAIL	FAIL
Pratt & Lambert	Isocyanate & Zinc Free	Universal HP Acrylic Primer Z6631	N/A	Acrylic Waterborne DTM Z6841	FAIL	PASS	Equal
Shield Products	Isocyanate & Zinc Free	SKU40003	N/A	SKU20059VC	FAIL	FAIL	PASS
Tesla	Isocyanate Free Reduced Zinc	TESLAN ZN Primer (Low VOC)	N/A	TESLAN Low VOC Urethane Topcoat (XUR-12041)	FAIL	FAIL	FAIL
EonCoat	Isocyanate & Zinc Free	N/A	N/A	EonCoat	FAIL	FAIL	FAIL
Carboline	Zinc Free	Carbomastic 615 with uCapsules	Carboguard 893	Carbothane 134MC	FAIL	FAIL	FAIL

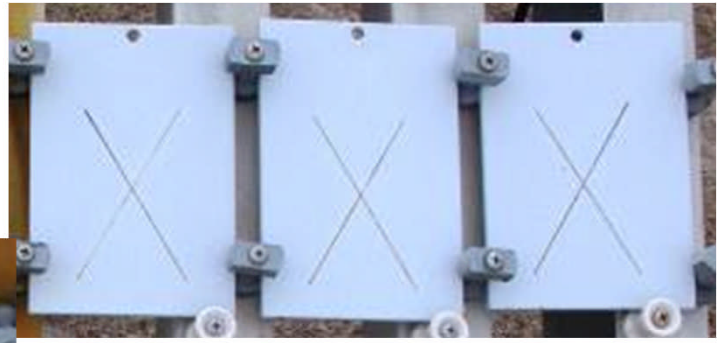
Environmentally-Preferable Launch Coatings

Based on the results of the Phase 1 Initial Coatings Testing the Following Coatings were Selected for Phase 2

Manufacturer	Type	Primer	Intermediate	Topcoat	Pot Life	Ease of Application	Surface Appearance	Atmospheric Exposure Test			Primer Heat Adhesion	Atmospheric Exposure Test	
								Corrosion	Blistering	Scribe		Color	Gloss
Carboline	Isocyanate Free	Carbozinc 11 WB	Carbotherm 3300	Carbocyrlic 3359	PASS	PASS	PASS	Equal	Equal	Equal	Equal	Equal	PASS
Polyset	Isocyanate Free	Ply-Zinc WB 18	N/A	Ply-Guard ME	PASS	PASS	PASS	PASS	Equal	Equal	Equal	Equal	FAIL
EonCoat	Isocyanate & Zinc Free	N/A	N/A	EonCoat	PASS	PASS	PASS	PASS	Equal	Equal	FAIL	FAIL	FAIL







Environmentally-Preferable Launch Coatings

Coating Systems Selected for Phase 1 Additional Coatings Testing

Manufacturer	Type	Primer	Intermediate	Topcoat
Dampney®	Isocyanate & Zinc Free	Protexior® 795	Protexior® 794	Epodur 791
Excalibur Paints	Isocyanate Free with Zinc	OZWBP-in-710 Water-borne IOZ Dust	EXWBP 700G Epoxy Primer	Aqua-Thane
Excalibur Paints	Isocyanate Free with Zinc	ACWP Series Zinc Modified Conversion Coat Primer	N/A	Aqua-Thane
PPG	Isocyanate Free with Zinc	Dimetcote® 21-5 Water-based Epoxy Primer	N/A	PSX 700 Polysiloxane Finish
Rust-Oleum®	Isocyanate & Zinc Free	S71 Water-based Epoxy Primer	N/A	S37 Metalmax® DTM Acrylic Urethane
Sherwin Williams	Contains Isocyanate Zinc Free	EURONAVY ES301K	N/A	Waterbased Acrolon 100
Sherwin Williams	Contains Isocyanate Zinc Free	Macropoxy 920-100	Pro Industrial 0 VOC Waterbased Epoxy	Waterbased Acrolon 100
Sherwin Williams	Contains Isocyanate with Zinc	Zinc Clad II+	646-100	Hi-Solids Polyurethane - 250
Wasser	Contains Isocyanate with Zinc	MC-Miozinc 100	MC-Miomastic 100	MC-Luster 100
Wasser	Contains Isocyanate Zinc Free	MC-Universal Primer 100	MC-Ferrox B 100	MC-Luster 100

Environmentally-Preferable Launch Coatings

Phase 1 CRITICAL Testing Results as Compared to the Baseline System										
Manufacturer	**Type**	**Primer**	**Intermediate**	**Topcoat**	**Pot Life**	**Surface Appearance**	**Ease of Application**	**Atmospheric Exposure Test**		
								Corrosion	**Blistering**	**Scribe**
Dampney®	Isocyanate & Zinc Free	Protexior® 795	Protexior® 794	Epodur 791	PASS	PASS	PASS	FAIL	Equal	FAIL
Excalibur Paints	Isocyanate Free with Zinc	OZWBP-in-710 Water-borne IOZ Dust	EXWBP 700G Epoxy Primer	Aqua-Thane	PASS	PASS	PASS	PASS	FAIL	Equal
PPG	Isocyanate Free with Zinc	Dimetcote® 21-5 Water-based Epoxy Primer	N/A	PSX 700 Polysiloxane Finish	PASS	PASS	PASS	Equal	Equal	Equal
Rust-Oleum®	Isocyanate & Zinc Free	S71 Water-based Epoxy Primer	N/A	S37 Metalmax® DTM Acrylic Urethane	PASS	PASS	PASS	FAIL	FAIL	FAIL
Sherwin Williams	Contains Isocyanate Zinc Free	EURONAVY ES301K	N/A	Waterbased Acrolon 100	PASS	PASS	PASS	FAIL	FAIL	FAIL
Sherwin Williams	Contains Isocyanate Zinc Free	Macropoxy 920-100	Pro Industrial 0 VOC Waterbased Epoxy	Waterbased Acrolon 100	PASS	PASS	PASS	FAIL	FAIL	FAIL
Sherwin Williams	Contains Isocyanate with Zinc	Zinc Clad II+	646-100	Hi-Solids Polyurethane - 250	PASS	PASS	PASS	Equal	Equal	Equal
Wasser	Contains Isocyanate with Zinc	MC-Miozinc 100	MC-Miomastic 100	MC-Luster 100	PASS	PASS	PASS	FAIL	Equal	FAIL
Excalibur Paints	Isocyanate Free with Zinc	ACWP Series Zinc Modified Conversion Coat Primer	N/A	Aqua-Thane	FAIL[1]	PASS	PASS	FAIL	FAIL	FAIL
Wasser	Contains Isocyanate Zinc Free	MC-Universal Primer 100	MC-Ferrox B 100	MC-Luster 100	PASS	FAIL[2]	Removed from testing			
FAIL[1] = The manufacturer provided replacement materials which were then applied successfully										
FAIL[2] = After curing, however, the entire surface of the panel blistered										

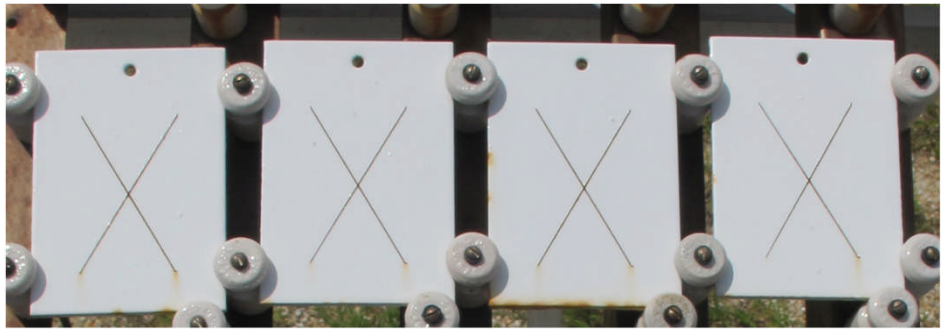
Environmentally-Preferable Launch Coatings

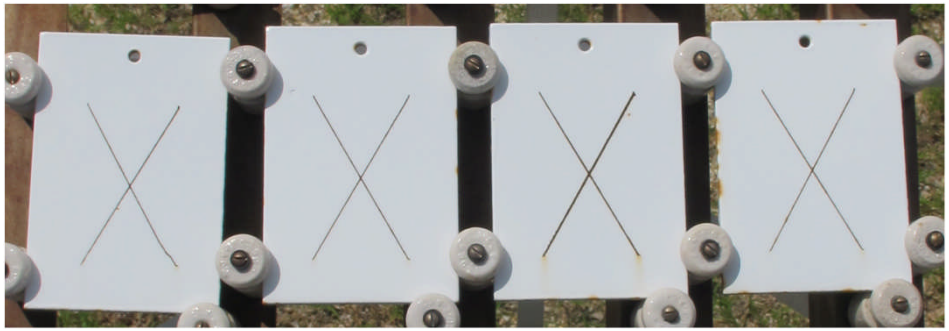
Phase 1 Testing Results as Compared to the Baseline System							
Manufacturer	**Type**	**Primer**	**Intermediate**	**Topcoat**	**Primer Heat Adhesion**	**Atmospheric Exposure Test**	
						Color	**Gloss**
Dampney®	Isocyanate & Zinc Free	Protexior® 795	Protexior® 794	Epodur 791	FAIL	FAIL	FAIL
Excalibur Paints	Isocyanate Free with Zinc	OZWBP-in-710 Water-borne IOZ Dust	EXWBP 700G Epoxy Primer	Aqua-Thane	PASS	Equal	FAIL
PPG	Isocyanate Free with Zinc	Dimetcote® 21-5 Water-based Epoxy Primer	N/A	PSX 700 Polysiloxane Finish	PASS	PASS	PASS
Rust-Oleum®	Isocyanate & Zinc Free	S71 Water-based Epoxy Primer	N/A	S37 Metalmax® DTM Acrylic Urethane	FAIL	FAIL	PASS
Sherwin Williams	Contains Isocyanate Zinc Free	EURONAVY ES301K	N/A	Waterbased Acrolon 100	FAIL	FAIL	Equal
Sherwin Williams	Contains Isocyanate Zinc Free	Macropoxy 920-100	Pro Industrial 0 VOC Waterbased Epoxy	Waterbased Acrolon 100	FAIL	FAIL	FAIL
Sherwin Williams	Contains Isocyanate with Zinc	Zinc Clad II+	646-100	Hi-Solids Polyurethane - 250	PASS	FAIL	FAIL
Wasser	Contains Isocyanate with Zinc	MC-Miozinc 100	MC-Miomastic 100	MC-Luster 100	FAIL	FAIL	PASS
Excalibur Paints	Isocyanate Free with Zinc	ACWP Series Zinc Modified Conversion Coat Primer	N/A	Aqua-Thane	FAIL	FAIL	PASS

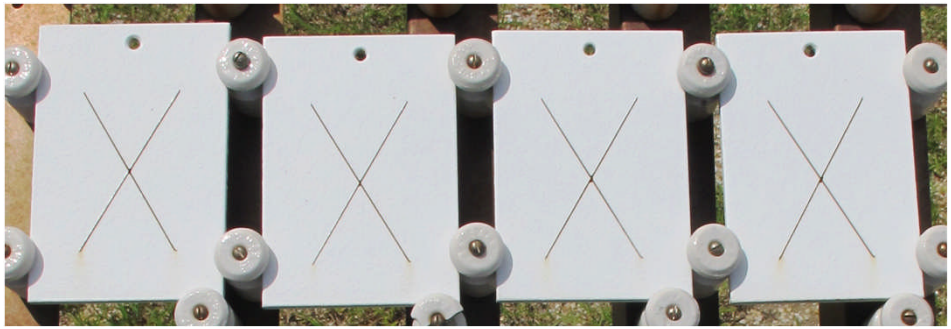
Environmentally-Preferable Launch Coatings

Based on the results of the Phase 1 Additional Coatings Testing the Following Coatings were Selected for Phase 2

Manufacturer	Type	Primer	Intermediate	Topcoat	Pot Life	Surface Appearance	Ease of Application	Atmospheric Exposure Test			Primer Heat Adhesion	Atmospheric Exposure Test	
								Corrosion	Blistering	Scribe		Color	Gloss
Excalibur Paints	Isocyanate Free with Zinc	OZWBP-in-710 Water-borne IOZ Dust	EXWBP 700G Epoxy Primer	Aqua-Thane	PASS	PASS	PASS	PASS	FAIL	Equal	PASS	Equal	FAIL
PPG	Isocyanate Free with Zinc	Dimetcote® 21-5 Water-based Epoxy Primer	N/A	PSX 700 Polysiloxane Finish	PASS	PASS	PASS	Equal	Equal	Equal	PASS	PASS	PASS
Sherwin Williams	Contains Isocyanate with Zinc	Zinc Clad II+	646-100	Hi-Solids Polyurethane - 250	PASS	PASS	PASS	Equal	Equal	Equal	PASS	FAIL	FAIL







Environmentally-Preferable Launch Coatings

Phase 2 Testing

Phase 2 Testing CRITICAL Requirements for Environmentally-preferable Coatings				
Test	**Test Specimen**	**Acceptance Criteria**	**Requirement**	**Test Methodology References**
Hypergol Compatibility	Coupon	Slight to Moderate Reactivity Observed: When test data based on visual observations with the unaided eye reveal reactivity (but no ignition) and/or any changes in the visual characteristics, bulk characteristics, and/or surface characteristics of the test sample	NASA-STD-6001	KSC MTB-175-88

- This test is specified in NASA-STD-6001 (*Flammability, Odor, Offgassing, and Compatibility Requirements and Test Procedures for Materials in Environments that Support Combustion*) and was identified as a testing requirement. Materials intended for use in space vehicles, specified test facilities, and specified ground support equipment (GSE) must meet the requirements of this document.
- This procedure evaluates the effects on coatings from casual exposure to hypergolic fluids [nitrogen tetroxide (N_2O_4), hydrazine (N_2H_4), and monomethylhydrazine (MMH)]. This procedure provides the method to determine if a fluid could react exothermally or spontaneously ignite on contact with a material.

Environmentally-Preferable Launch Coatings

Phase 2 Testing

Phase 2 Testing				
Test	**Test Specimen**	**Acceptance Criteria**	**Requirement**	**Test Methodology References**
Cure Time (MEK Solvent Rub)	Coupon	Coating will be tested every two (2) days for a total of 14 days; No effect on surface or coating on the cloth (Resistance Rating 5)		ASTM D 4752
Tensile (Pull-off) Adhesion	Coupon	Pull-off strength achieved at time of failure equal to or better than control coatings		ASTM D 4541
Removability	Coupon	Less than one minute to penetrate substrate; Tested during Reparability and Abrasion Resistance Tests; Measure Dry Film Thickness of remaining coating		ASTM G 155, SSPC-PA-2
Reparability	Coupon	Ease of removal and replacement of damaged areas of the test coatings, color matching of aged versus new material; No streaks, blistering, voids, air bubbles, over-spray "halo", cratering, lifting, blushing, or other surface irregularities, No peel away of the repaired coating during the dry tape adhesion test		ASTM D 523, ASTM D 2244, ASTM D 3359
Mandrel Bend Flexibility	Coupon	No peeling or delamination from the substrate and no cracking greater than ¼-inch from the edges.		ASTM D 522

- These tests are not required per NASA-STD-5008B, however, these tests are excellent indicators of future coating performance.

Environmentally-Preferable Launch Coatings

Remaining Tests

Phase 2 Testing Results										
Manufacturer	**Type**	**Primer**	**Intermediate**	**Topcoat**	**Hypergol Compatibility**	**Cure Time (MEK Solvent Rub)**	**Tensile (Pull-Off) Adhesion**	**Removability**	**Reparability**	**Mandrel Bend Flexibility**
Carboline	Isocyanate Free	Carbozinc 11 WB	Carbotherm 3300	Carbocyrlic 3359	June	FAIL	FAIL	June	June	PASS
Polyset	Isocyanate Free	Ply-Zinc WB 18	N/A	Ply-Guard ME	June	FAIL	PASS	June	June	FAIL
EonCoat	Isocyanate & Zinc Free	N/A	N/A	EonCoat	June	PASS	FAIL	June	June	FAIL

Manufacturer	**Type**	**Primer**	**Intermediate**	**Topcoat**	**Hypergol Compatibility**	**Cure Time (MEK Solvent Rub)**	**Tensile (Pull-Off) Adhesion**	**Removability**	**Reparability**	**Mandrel Bend Flexibility**
Excalibur Paints	Isocyanate Free with Zinc	OZWBP-in-710 Water-borne IOZ Dust	EXWBP 700G Epoxy Primer	Aqua-Thane	June	June	May	June	June	June
PPG	Isocyanate Free with Zinc	Dimetcote® 21-5 Water-based Epoxy Primer	N/A	PSX 700 Polysiloxane Finish	June	June	May	June	June	June
Sherwin Williams	Contains Isocyanate with Zinc	Zinc Clad II+	646-100	Hi-Solids Polyurethane - 250	June	June	May	June	June	June

Environmentally-Preferable Launch Coatings

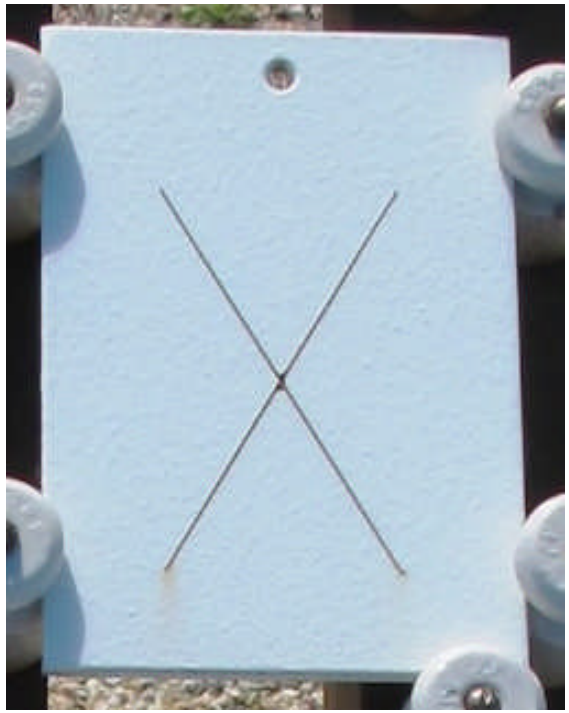
Collaborative NASA / ESA Test Program

Test panels

- Flat panel = six (6) inch x four (4) inch x 3/16 inch panels fabricated from ASTM A 36 hot rolled carbon steel
- Composite carbon steel = six (6) inch x four (4) inch x 3/16 inch panels with a one (1) inch channel welded on front face, fabricated from ASTM A 36 hot rolled carbon steel

2 sets of panels per coating system

- 1 set - Primer only
- 1 set - Full coating system



Environmentally-Preferable Launch Coatings

Collaborative NASA / ESA Test Program

Phase 1 Testing				
Test	**Test Specimen**	**Acceptance Criteria**	**Requirement**	**Test Methodology References**
Pot Life	Mixed Coating System	Based on Applicator Evaluation: Equal to or better than control coating	NASA-STD-5008B	None
Ease of Application	Coupon	Based on Applicator Evaluation: Smooth coat, with acceptable appearance, no runs, bubbles or sags; Ability to cover the properly prepared/primed substrate with a single coat (one-coat hiding ability); Measure Dry Film Thickness.	NASA-STD-5008B	SSPC-PA-2
Surface Appearance	Coupon	Based on Applicator Evaluation: No streaks, blistering, voids, air bubbles, cratering, lifting, blushing, or other surface defects/irregularities; No micro-cracks observable at 10X magnification	NASA-STD-5008B	ASTM D 523 ASTM D 2244
Atmospheric Exposure	Coupon	Attain a rating of not less than 8 in accordance with ASTM D610; 18 months initial acceptance, 5 years for final acceptance	NASA-STD-5008B	ASTM D 610, ASTM D 714, ASTM D 1654
	Coupon	Apply an acid-slurry {0.3 micron Al^2O^3 particles in a 10% (by volume) HCl solution} at six week intervals		ASTM D 610, ASTM D 714, ASTM D 1654
	Coupon	Retain gloss and color on prolonged outdoor exposure	NASA-STD-5008B	ASTM D 523
Primer Heat Adhesion	Coupon	No loss of adhesion after heating @ 400 °C (750 °F) for 24 hours	NASA-STD-5008B	ASTM D 4541
Hypergol Compatibility	Coupon	Slight to Moderate Reactivity Observed: When test data based on visual observations with the unaided eye reveal reactivity (but no ignition) and/or any changes in the visual characteristics, bulk characteristics, and/or surface characteristics of the test sample	NASA-STD-6001	KSC MTB-175-88

Environmentally-Preferable Launch Coatings

Collaborative NASA / ESA Test Program

Phase 2 Testing				
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Removability	Coupon	Less than one minute to penetrate substrate; Tested during Reparability and Abrasion Resistance Tests; Measure Dry Film Thickness of remaining coating		ASTM G 155, SSPC-PA-2
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Mandrel Bend Flexibility	Coupon	No peeling or delamination from the substrate and no cracking greater than ¼-inch from the edges.		ASTM D 522

Environmentally-Preferable Launch Coatings

Summary

- Metals require periodic maintenance activity to guard against the insidious effects of corrosion and thus ensure that structures meet or exceed design or performance life.
- Due to the regulations and restrictions on the use of HAPs , VOCs and isocyanates in coatings, currently approved coatings could become unavailable.
- The focus of this project is corrosion resistance and survivability with the goal to reduce the amount of maintenance required to preserve the performance of launch facilities while reducing mission risk.
- The project compares coating performance of the selected alternatives to existing coating systems or standards.
- Environmentally preferred coatings were subjected to critical requirement and performance testing.
- Testing is ongoing, with none of the coatings being tested passing all tests.
- Additional coating candidates should be considered for future testing.
- NASA and ESA will collaborate on a joint project to evaluate environmentally preferred coatings for use on launch structures, ground support equipment and other critical steel structures.