National Aeronautics and Space Administration (NASA)
Acquisition Pollution Prevention (AP2) Office

Potential Alternatives Report

For Validation of Alternatives to Aliphatic Isocyanate Polyurethanes

FINAL

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May 19, 2006

Prepared by
International Trade Bridge (ITB), Inc.
Beavercreek, OH 45432

Submitted by
NASA Acquisition and Pollution Prevention Program Office

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PREFACE

This report was prepared by International Trade Bridge, Inc. (ITB) through the National Aeronautics and Space Administration (NASA) Acquisition Pollution Prevention (AP2) Office under Contract Number NAS10-03029 Task Order No. 1. The structure, format, and depth of technical content of the report were determined by the NASA AP2 Office, Government contractors, and other Government technical representatives in response to the specific needs of this project.

Information in this report was leveraged from the following documents:

> Logistics Environmental Office Pollution Prevention Project, *Air Force Potential Alternative Report, ZHTV02W147, Low/No-VOC Corrosion-preventive Coatings for ICBM Missile Support Equipment—Phase 1*, dated June 4, 2003; prepared by International Trade Bridge (ITB), Inc.; under GSA Contract GS05T02BMM1604, Order Number 5TS5702D294

> Engineering and Technical Services for Joint Group on Acquisition Pollution Prevention (JG-APP) Pilot Projects, *Potential Alternatives Report (TI-A-1-1) for Alternatives to High-Volatile Organic Compound Primers and Topcoats Containing Methyl Ethyl Ketone, Toluene, and Xylene*, dated February 5, 1998; prepared by National Defense Center for Environmental Excellence (NDCEE), operated by Concurrent Technologies Corporation (CTC); under Contract No. DAAA21-93-C-0046, Task No. N.072, CDRL No. A004.

We wish to acknowledge the invaluable contributions provided by all the organizations involved in the creation of this document.

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EXECUTIVE SUMMARY

Isocyanates, as found in aliphatic isocyanate polyurethanes, were the identified hazardous material (HazMat) targeted for elimination under this project.

This Potential Alternatives Report (PAR) provides technical analyses of identified alternatives to the current coatings, criteria used to select alternatives for further analysis, and a list of those alternatives recommended for testing. It also contains a preliminary cost-benefit analysis (CBA) to quantify the estimated capital and process costs of coating removal alternatives and cost savings relative to the current coating removal processes.

The initial coating alternatives list was compiled using existing PARs and Joint Test Reports (JTRs), literature searches and center participant recommendations. The involved project participants initially considered eighteen (18) alternative coatings:

- Ameron PSX 700
- Ameron PSX 1001
- Carboline Carboxane 950
- Carboline Carboxane 2000
- Hempel Hempaxane 55000
- Integrated Polymer Industries IPI-Superbarrier
- Integrated Polymer Industries IPN-FlexFair
- International Protective Coatings Interfine 878
- International Protective Coatings Interfine 979
- Jotun Jotacote PSO
- Keeler & Long Megaflon
- Kimetsan Limited AquaSurTech (AST) D45-AMS
- Revodyne Industries Industrial Coating
- Sherwin Williams Centurion
- Sherwin Williams Fast Clad HB Acrylic
- Sherwin Williams Polysiloxane XLE
- Sherwin Williams SHER-CRYL HPA
- Tego Silikoftal ED

In early 2004, stakeholders identified specific coatings as potential alternatives to the current coating based on available information about these coatings. Technical merits and the potential environmental, safety, and occupational health (ESOH) impacts of these coatings were evaluated. Project participants used this information to select coatings for testing in accordance with the Joint Test Protocol entitled *Joint Test Protocol for Validation of Alternatives to Aliphatic Isocyanate Polyurethanes*, and the Field Test Plan entitled *Field Evaluations Test Plan for Validation of Alternatives to Aliphatic Isocyanate Polyurethanes*, both of which were prepared by ITB. Results of the testing will be documented in a Joint Test Report. The coatings selected for testing were:

- Ameron PSX 1001
- Carboline Carboxane 2000
- International Protective Coatings Interfine 878
- International Protective Coatings Interfine 979
- Kimetsan Limited AquaSurTech (AST) D45-AMS
- Sherwin Williams Fast Clad HB Acrylic
- Sherwin Williams Polysiloxane XLE
- Sherwin Williams SHER-CRYL HPA

A preliminary cost benefit analysis will be performed to determine if implementation of candidate coatings is economically justified.

1. INTRODUCTION

Headquarters National Aeronautics and Space Administration (NASA) chartered the Acquisition Pollution Prevention (AP2) Office to coordinate agency activities affecting pollution prevention issues identified during system and component acquisition and sustainment processes. The primary objectives of the AP2 Office are to:

- Reduce or eliminate the use of hazardous materials (HazMats) or hazardous processes at manufacturing, remanufacturing, and sustainment locations.
- Avoid duplication of effort in actions required to reduce or eliminate HazMats through joint center cooperation and technology sharing.

To reduce HazMats, the AP2 process first identifies the HazMat, related process(es), and affected substrate(s) or part(s). Details of the coating process, such as process flow diagrams; process description; equipment requirements; anticipated changes in material usage; wastes and emissions; environmental, safety, and occupational health (ESOH) issues are part of this Potential Alternatives Report (PAR).

Identifying and selecting alternative materials and technologies that have the potential to reduce the identified HazMats and hazardous air pollutants (HAPs), while incorporating sound corrosion prevention and control technologies, is a complicated task due to the fast pace at which new technologies emerge and rules change. The alternatives are identified through literature searches, electronic database and Internet searches, surveys, and/or personal and professional contacts. Available test data was then compiled on the proposed alternatives to determine if the materials meet the test objectives or if further laboratory or field-testing will be required.

After reviewing technical information documented in the PAR, government representatives, technical representatives from the affected facilities, and other stakeholders involved in the process will select the list of viable alternative coatings for consideration and testing under the project's Joint Test Protocol entitled *Joint Test Protocol for Validation of Alternatives to Aliphatic Isocyanate Polyurethanes* and Field Test Plan entitled *Field Evaluations Test Plan for Validation of Alternatives to Aliphatic Isocyanate Polyurethanes*, both prepared by ITB. Test results will be reported in a Joint Test Report upon completion of testing. The selection rationale and conclusions are documented in this PAR.

A cost benefit analysis will be prepared to quantify the estimated capital and process costs of coating alternatives and cost savings relative to the current coating processes, however, some initial cost data has been included in this PAR.

For this coatings project, isocyanates, as found in aliphatic isocyanate polyurethanes, were identified as the target HazMat to be eliminated. Table 1-1 lists the target HazMats, the related process and application, current specifications, and affected programs.

Table 1-1 Target HazMat Summary				
Target HazMat	**Current Process**	**Applications**	**Current Specifications**	**Candidate Parts/Substrates**
Isocyanates used in urethane coatings	Conventional spray and brush application	Any application where a high-gloss finish is required	NASA Approved Products (listed in Appendix B of NASA-STD-5008); AFSPC Approved Products	Carbon Steel

This PAR focuses on isocyanate-free coatings for structural steel, as required by the project participants. The following subsections describe the coating systems as they relate to applications used by the participants, including description of materials, process flow diagrams, amounts of materials used, and hazardous waste generated.

1.1. Background

NASA and Air Force Space Command (AFSPC) have similar missions and therefore similar facilities and structures in similar environments. Both are responsible for a number of facilities/structures with metallic structural and non-structural components in highly and moderately corrosive environments. Regardless of the corrosivity of the environment, all 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 standard practice for protecting metallic substrates in atmospheric environments is the application of an applied coating system. Applied coating systems work via a variety of methods (barrier, galvanic and/or inhibitor) and adhere to the substrate through a combination of chemical and physical bonds.

The most common topcoats used in coating systems are polyurethanes that contain isocyanates. Isocyanates are compounds containing the isocyanate group (-NCO). They react with compounds containing alcohol (hydroxyl) groups to produce polyurethane polymers, which are components of polyurethane foams, thermoplastic elastomers, spandex fibers, and the polyurethane paints used in NASA and AFSPC applications.

The use of isocyanates in coatings is being threatened today by environmental concerns and increasing regulations. This pressure to reduce or remove isocyanates is growing at a significant rate. As a result, NASA and AFSPC are searching for isocyanate-free coating alternatives.

1.2. Objectives and Scope of Work

The primary objective of this effort is to demonstrate and validate alternatives to aliphatic isocyanate polyurethanes. Successful completion of this project will result in one or more isocyanate-free coatings qualified for use at AFSPC and NASA centers participating in this project.

One of the objectives of the effort is to develop a concise, focused PAR documenting the technical, production, cost, and environmental information about the baseline coating processes. ESOH issues pertaining to the baseline and alternative coatings will be discussed.

1.3. Isocyanate-Free Coatings Overview

Isocyanates are compounds containing the isocyanate group (-NCO). They react with compounds containing alcohol (hydroxyl) groups to produce polyurethane polymers, which are components of polyurethane foams, thermoplastic elastomers, spandex fibers, and polyurethane paints.

The Occupational Health & Safety Administration (OSHA) states that the effects of isocyanate exposure include irritation of skin and mucous membranes, chest tightness, and difficult breathing. 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.

2. CURRENT BASELINE PROCESS

This PAR focuses on coating processes that use aliphatic isocyanate polyurethanes, as required by the project participants. The following subsections describe the coating process as it relates to applications used by the participants, including description of materials, process flow diagrams, amounts of coatings used and hazardous waste generated.

The coating systems selected as the controls for testing are:

- Cathacoat 304 (Primer), Devron 201 (Intermediate Coat), and Devthane 359 DTM (Topcoat) produced by ICI Devoe Coatings Co.
- Carbozinc (CZ)-11HS (Primer), Carboguard 893 (Intermediate Coat), and Carbothane 134 HB (Topcoat) produced by Carboline Company.

The baseline process information was gathered by method of interview of participants. The descriptions below are based on "typical" and generalized coating application processes, and are not the exact processes used by any of the participants of the AP2 Alternatives to Aliphatic Isocyanate Polyurethanes project.

The current process flow diagram for priming and topcoating is shown in Section 2.1 and the current process description and process equipment are described in Sections 2.2 and 2.3, respectively. Material usage, and wastes and emissions are described in Sections 2.4 and 2.5, respectively.

2.1. Process Flow Diagram

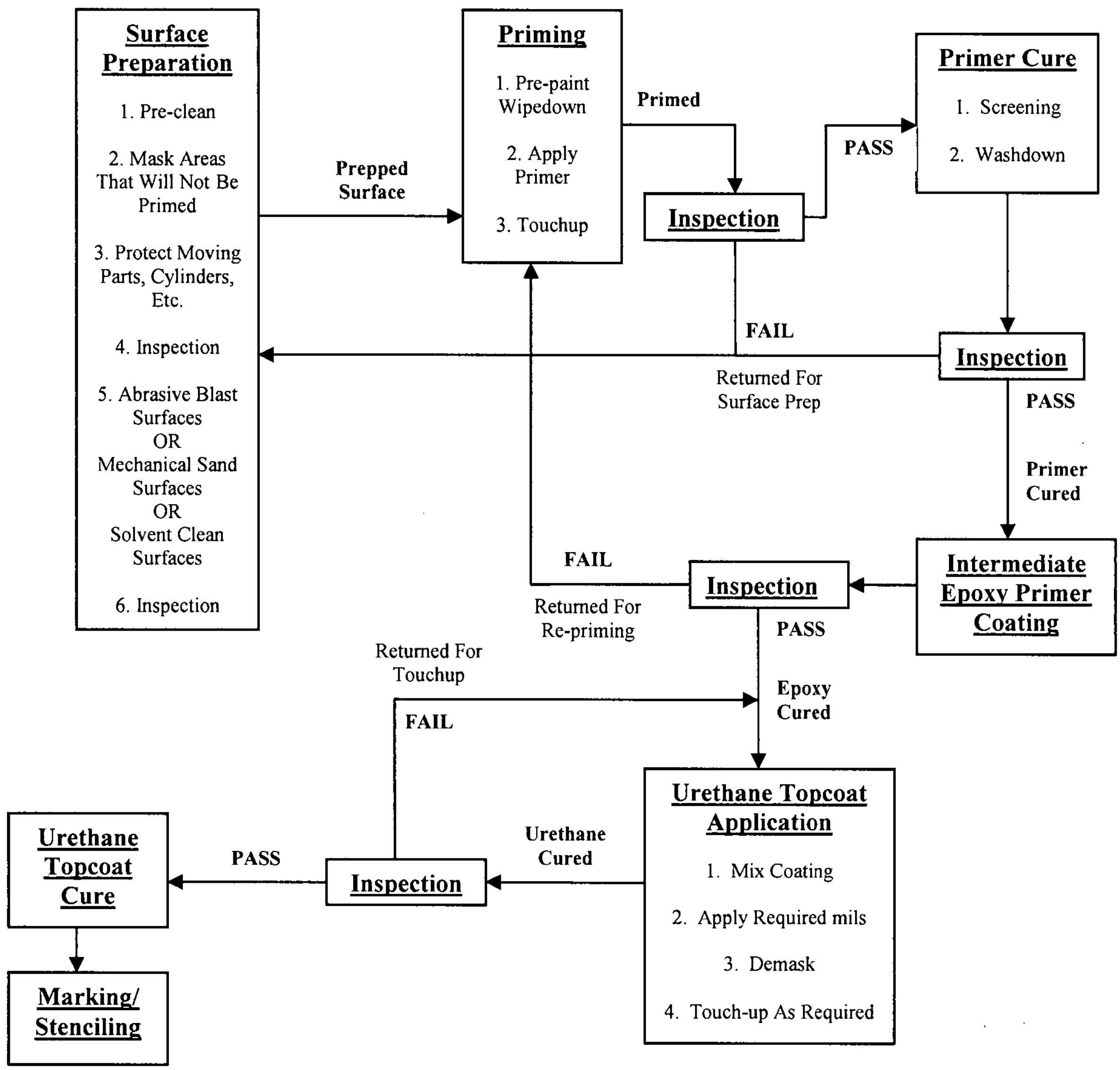
The coating process includes a standard six step coating process. First, the parts undergo surface preparation, such as cleaning, scuff sanding, or abrasive blasting and masking to protect areas on substrates that are not to be coated. Secondly, those parts requiring additional adhesion enhancement or corrosion protection receive one or two coats of primer and then are cured. Then the primed parts receive an intermediate epoxy primer coating. Next the parts are topcoated with a specified coating and cured. Markings such as equipment identification, caution and warning information, operational instructions, etc., are applied using such materials as: aerosol spray, metal data plates, and vinyl decals. The Baseline Process Flow Diagram is shown in Figure 2-1.

2.2. Process Description

As shown in Figure 2-1, the typical organic coating process is surface preparation, priming, intermediate epoxy primer coating, topcoating and marking operations. The coating spray process steps are described below.

In accordance with technical data requirements and coating manufacturer recommendations, coatings are not normally applied under unfavorable atmospheric conditions, such as high humidity, strong drafts, or low temperatures.

Figure 2-1 Process Flow Diagram of Baseline Coating Process



2.2.1. Surface Preparation

Surface preparation, such as cleaning and masking, takes place before priming. Pre-cleaning prior to any surface preparation is the first essential step in successful coating application. Pre-cleaning may be accomplished by water-based cleaning compounds or acceptable solvents to remove carbon, soils, and other contaminants that may become concentrated on the surfaces and in corners and crevices preventing proper coating adherence. Other cleaning operations include various surface preparation activities such as abrasive blasting, manual sanding, or solvent cleaning of the substrate to prepare the surfaces to accept a coating.

To enhance corrosion protection and increase coating adherence many coating manufacturers require the bare metal substrates receive a conversion coating pretreatment prior to coating. The pretreatment may range from iron or zinc phosphate for carbon steel surfaces to chromate conversion coatings or non-chromate conversion coatings for aluminum and magnesium. Zinc phosphate and chromate conversion materials are considered HazMats and must be treated and disposed of in accordance with the local, state, and federal requirements of the locations where the operations occurred.

Adhesive-backed crepe masking tape is typically used for surface masking of small areas not being painted. Additionally, a combination of tape, plastic sheeting, and masking paper may be used to mask large areas. An estimate of the volume of masking materials that are used will vary and is dependent on dimensions of the surface being painted. Actual hours involved in masking are dependent on the size and configuration of the surface being painted.

Waste generated as a result of the surface preparation operations may include spent abrasive media, soiled rags, and masking materials. This media will be considered a HazMat if the primer and topcoat being removed contains chromate and/or heavy metals. Cleaning compound residue may contain oils, cadmium, hydraulic fluid, solvents, and other contaminants and must be treated and disposed of in accordance with the local, state and federal requirements of the locations where the operations occurred.

The equipment, materials, wastes and emissions of surface preparation will not be quantified and discussed in detail as this step will not change with the approval of any new coatings.

2.2.2. Priming and Curing

After the surface of the parts are properly prepared, normally a primer is mixed, strained, and allowed to stand for a period of time to allow the different components to react. The material is then thinned to the proper viscosity (if required) and applied by brush or spraying with airless, conventional pots, or pressure feed paint spray equipment.

After priming, surfaces are allowed to cure at ambient temperature for 12 to 36 hours. Only one wet coat of primer is typically applied to a surface; however, if an engineering drawing specifies more than one coat, then that number of primer coats is applied with air curing between each coat. Excessive primer build-up is normally avoided to prevent intercoat adhesion failures.

Paint spray guns are normally flushed with the appropriate solvent prior to each operator break and at the end of each shift. Newer cleaning equipment may be able to capture Volatile Organic Compounds (VOCs) at the source. If not captured, VOCs associated with equipment cleaning are exhausted to the atmosphere. Spent solvents are sometimes distilled and reused for pre-paint wipe down or paint gun cleaning.

To ensure freshly painted surfaces are not contaminated by dust and other particulate matter, painting areas are cleaned on a regular basis, with the cleaning interval dependent on usage. The painting operations debris such as over-spray materials, paint chips, abrasive media, rags, masking materials, paint strainers, floor covering paper, and leftover pre-catalyzed coatings are collected in drums and disposed of in accordance with the local, state, and federal requirements of the locations where the operations occurred.

2.2.3. Intermediate Epoxy Primer

After areas are sufficiently primed and cured, an intermediate epoxy primer coating is applied by brush work or spraying and then cured per the manufacturer's directions prior to being topcoated.

Spray guns are normally flushed with an approved coating solvent before each operator break and at the end of each shift. Unless captured, VOCs from equipment cleaning are vented to the atmosphere. Used solvents or thinners may be recycled if an appropriate distiller is available. Otherwise, the waste solvents or thinners are collected and disposed of in accordance with the local, state, and federal requirements for the locations where the operations occurred.

Surface coating condition should be inspected during, and at the conclusion of, the painting operations.

2.2.4. Topcoating

After areas are sufficiently primed and cured, a topcoat is applied by field brush, roll or spraying and then cured per the manufacturer's directions.

Spray guns are normally flushed with an approved coating solvent before each operator break and at the end of each shift. Unless captured, VOCs from equipment cleaning are vented to the atmosphere. Used solvents or thinners may be recycled if an appropriate distiller is available. Otherwise, the waste solvents or thinners are collected and disposed of in accordance with the local, state, and federal requirements for the locations where the operations occurred.

Surface coating condition should be inspected during, and at the conclusion of, the painting operations. During painting operations, wet film coating thickness is monitored manually using a wet film gauge. After coating operations are complete, parts are normally allowed to cure at ambient temperature for 72 hours. Coatings are visually inspected for appearance and coating thickness, and touchup coatings are applied as required. The Dry Film Thickness (DFT) of the coating system is verified using a non-destructive film thickness gauge.

Demasking normally does not occur for at least four hours after topcoating to ensure that the finish does not get damaged. After demasking, coating touchup may be accomplished on any areas where coatings are missing. Nonchromate-containing masking materials are segregated, when possible for disposal in a landfill.

Marking or stenciling occurs after the coating has cured to the touch. Marking or stenciling may be accomplished with vinyl die-cut lettering, paint spray using HVLP stencil spray guns, or with a stencil and paint spray can. The masking tape and paper associated with the vinyl lettering is disposed of as a solid waste. All other nonchromate containing marking or stenciling materials are segregated (when possible) for disposal in a landfill.

2.3. Process Equipment

Equipment that is required for surface preparation is not discussed, as surface preparation is unlikely to change with the viable alternatives. Current process equipment for priming and topcoating specifications are brush or airless, conventional pots, or pressure feed paint spray equipment. If spray equipment is used, a compressor is required.

2.4. Materials Usage

The materials typically consumed in priming and topcoating operations are summarized in Table 2-1. Actual amounts of materials consumed during painting operations will vary between locations and are dependent on a number of factors.

Table 2-1 Baseline Priming and Topcoating Material Usage

Process Step	Material
Primer Coating	Primer
	Thinner (if required)
	Paint filters
	Lint free wipe cloths
	Appropriate primer solvent
Intermediate Epoxy Primer Coating	Intermediate epoxy primer
	Thinner (if required)
	Paint filters
	Lint free wipe cloths
	Appropriate epoxy solvent
Topcoating	Topcoat
	Thinner (if required)
	Paint filters
	Lint free wipe cloths
	Appropriate topcoat solvent

NOTE: This table does not reflect materials that are required for surface preparation, as surface preparation is unlikely to change with the viable alternatives.

2.5. Wastes and Emissions

A summary of the wastes and emissions from priming, intermediate epoxy priming and topcoating is presented in Table 2-2. Actual amounts of waste generated and emissions emitted during painting operations will vary between locations and are dependent on a number of factors.

Table 2-2 Baseline Wastes and Emissions

Process Step	Waste or Emissions
Primer Application	Pre-catalyzed primer (*may contain chromates*)
	Rags, debris, and paint filters (*residue may contain strontium chromate*)
	Waste paint thinner (if required)
	VOC emissions
Primer Curing	VOC emissions
Intermediate Epoxy Primer Application	Pre-catalyzed epoxy primer
	Rags, debris, and paint filters
	Waste paint thinner (if required)
	VOC emissions
Intermediate Epoxy Primer Curing	VOC emissions
Topcoat Application	Pre-catalyzed topcoat
	Rags, debris, and paint filters
	Waste paint thinner (if required)
	VOC emissions
	Masking materials (removed and disposed of after topcoat application)
Topcoat Curing	VOC emissions

NOTE: This table does not reflect wastes and emissions from surface preparation, as surface preparation is unlikely to change with the viable alternatives.

2.6. Environmental, Safety, and Occupational Health (ESOH) Status

The hazardous materials targeted for reduction in this project are isocyanates found in polyurethane coatings. An ESOH analysis of the baseline process was performed based on readily available information from the coating manufacturers to determine whether there were any conspicuous ESOH issues that needed to be addressed.

The results of the ESOH analysis for the baseline materials are included in Section 5 along with the viable alternatives. A detailed description of the ESOH analysis process, including "Environmental Issues" and "Health and Safety Issues" is provided in Appendix A.

3. IDENTIFIED ALTERNATIVES AND PRELIMINARY SCREENING

In order to identify viable alternatives to solvent-borne topcoats and primers, existing PARs and JTRs were reviewed and other surveys were performed to leverage available test and performance data for this project.

3.1. Alternative Technology Selection

Eighteen (18) alternatives were initially identified. Proposed alternatives to the existing baseline coating systems are listed below:

- Ameron PSX 700
- Ameron PSX 1001
- Carboline Carboxane 950
- Carboline Carboxane 2000
- Hempel Hempaxane 55000
- Integrated Polymer Industries IPI-Superbarrier
- Integrated Polymer Industries IPN-FlexFair
- International Protective Coatings Interfine 878
- International Protective Coatings Interfine 979
- Jotun Jotacote PSO
- Keeler & Long Megaflon
- Kimetsan Limited AquaSurTech (AST) D45-AMS
- Revodyne Industries Industrial Coating
- Sherwin Williams Centurion
- Sherwin Williams Fast Clad HB Acrylic
- Sherwin Williams Polysiloxane XLE
- Sherwin Williams SHER-CRYL HPA
- Tego Silikoftal ED

3.2. Potential Alternative Tables

A brief description of the identified alternatives is listed in the following tables. Specific environmental safety and health (ESOH) data for each material is contained Section 5. Some of the tables were not completed because the product was removed from consideration during the initial screening. If so, this is noted in the "Comments" section of the table and the reasoning described in further detail in Section 4.

Table 3-1 Ameron Self Priming PSX 700 Siloxane

Material	Material Description:	Estimated Cost Factors	Manufacturer
Name: PSX 700 Siloxane Topcoat	This product is an acrylic polysiloxane hybrid. It is a self-priming, high-gloss topcoat that provides excellent adhesion and resistance to acid and corrosion.	**Unit Cost:** $	Ameron International 13010 Morris Rd, Suite 400 Alpharetta, GA 30004 (678) 393-0653
EPCRA: ☐ Yes ☒ **No** **Material:**		**Unit Size:** 1 gallon kit	
CERCLA: ☐ Yes ☒ **No** **Material:**		**Est. Coverage @ 3 mils DFT:** 481 ft²/gallon	
HAPS: ☐ Yes ☒ **No** **Material:**		**Est. Material Cost Per Ft²:** $	**Est. Coating Life:** 5-7 years
VOC: ☒ **Yes** **204 g/L** ☐ No	**Product Hazard Ranking and Rationale:** **Low:** Does not contain SARA III, HAZMAT, or HAPS. Catalyst does not contain/emit isocyanate		
Recommended Surface Prep: Requires SP-6 **Recommended Pretreatment:** No Pretreatment—Direct to Metal	**Advantages:** • Self-priming • Can be applied over inorganic zinc • Cures at room temperature • Resists humidity and moisture	**Disadvantages:** • Pot Life - 1½ hours @ 90°F	
Applicable Substrates: ☒ Aluminum ☒ Carbon Steel ☒ Stainless Steel	**Manufacturer Recommended Coating System:**		
Comments: **REMOVED FROM CONSIDERATION IN THIS PROJECT BECAUSE PRODUCT HAS ALREADY HAD LIMITED USE AT VARIOUS CENTERS.**			**Recommended For Testing:** ☐ Yes ☒ **No**

Table 3-2 Ameron PSX 1001

Material	Material Description:	Estimated Cost Factors	Manufacturer
Name: PSX 1001 Acrylic Polysiloxane	This product is an acrylic polysiloxane hybrid. A single-component, high gloss topcoat that provides a polyurethane-like finish without the isocyanates.	**Unit Cost:** $ 42.75	Ameron International 13010 Morris Road, Suite 400 Alpharetta, GA 30004 (678) 393-0653
EPCRA: ☒ **Yes** ☐ No **Material:** Xylene; 1,2,4-trimethyl benzene; ethyl benzene; methanol; benzene; toluene		**Unit Size:** 1 gallon	
CERCLA: ☒ **Yes** ☐ No **Material:** Xylene; methanol; ethyl benzene; toluene; and proprietary ingredient		**Est. Coverage @ 3 mils DFT:** 330 sq ft/gal	
HAPS: ☒ **Yes** ☐ No **Material:** Xylene; ethyl benzene; toluene		**Est. Material Cost Per Ft^2:** $ 0.13	**Est. Coating Life:** 7 years
VOC: ☒ **Yes** **384 g/L** ☐ No	**Product Hazard Ranking and Rationale:** **Medium:** Toxicity of constituents is Medium-Low, while the exposure risk is Medium-High. An average of the toxicity and exposure risks yields a Medium overall ranking		
Recommended Surface Prep: Previously painted steel: SSPC-SP10 New steel: SSPC-SP6 Anchor profile: 1-2 mils **Recommended Pretreatment:** Surface must be cleaned, dry, undamaged and free of all contaminants, including salt deposits.	**Advantages:** • Single component • Excellent gloss retention • Unlimited recoat window • Compatible with inorganic zinc rich primers, epoxies, etc.	**Disadvantages:** • Flash Point = 66 °F; OSHA: Flammable – Class IB • Closed containers may explode when exposed to extreme heat and pressure buildup	
Applicable Substrates: ☒ Aluminum ☒ Carbon Steel ☒ Stainless Steel	**Manufacturer Recommended Coating System:** • Primer: Ameron Dimetcote 9H (VOC: 323 g/L) • Intermediate: Ameron 383H (VOC: 231 g/L)		
Comments: **Include in testing**			**Recommended For Testing:** ☒ **Yes** ☐ No

Table 3-3 Carboline Carboxane 950

Material	Material Description:	Estimated Cost Factors	Manufacturer
Name: Carboxane 950	A fluorourethane finish that provides excellent color and gloss retention and exterior weathering characteristics.	**Unit Cost:** $	Carboline 350 Hanley Industrial Court St. Louis, MO 63144 (800) 848-4645
EPCRA: ☒ **Yes** ☐ No **Material:** Xylene, ethyl benzene		**Unit Size:** 1 gallon	
CERCLA: ☐ Yes ☐ No **Material:**		**Est. Coverage @ 3 mils DFT:** 233 sq ft/gal	
HAPS: ☒ **Yes** ☐ No **Material:** Xylene, ethyl benzene		**Est. Material Cost Per Ft^2:** $	**Est. Coating Life:** 10-15 years
VOC: ☒ **Yes** **396 g/L** ☐ No	**Product Hazard Ranking and Rationale:**		
Recommended Surface Prep:	**Advantages:**	**Disadvantages:** • Contains Isocyanates	
Recommended Pretreatment:			
Applicable Substrates: ☒ Aluminum ☒ Carbon Steel ☒ Stainless Steel	**Manufacturer Recommended Coating System:**		
Comments: **REMOVED FROM FURTHER CONSIDERATION BECAUSE THE PRODUCT CONTAINS ISOCYANATES**			**Recommended For Testing:** ☐ Yes ☒ **No**

<table>
<tr><th colspan="4">Table 3-4 Carboline Carboxane 2000</th></tr>
<tr><th>Material</th><th>Material Description:</th><th>Estimated Cost Factors</th><th>Manufacturer</th></tr>
<tr><td>Name:
Carboxane 2000 Modified Siloxane Hybrid</td><td rowspan="4">This product is an epoxy polysiloxane hybrid.

A premium, ultra durable coating that provides outstanding gloss and color retention for exterior exposures.</td><td>Unit Cost:
$ 96.50</td><td rowspan="3">Carboline
350 Hanley Industrial Court
St. Louis, MO 63144
(800) 848-4645</td></tr>
<tr><td>EPCRA: ☐ Yes ☒ No
Material:</td><td>Unit Size:
1 gallon</td></tr>
<tr><td>CERCLA: ☐ Yes ☒ No
Material:</td><td>Est. Coverage @ 3 mils DFT:
455 sq ft/gal</td></tr>
<tr><td>HAPS: ☐ Yes ☒ No
Material:</td><td>Est. Material Cost Per Ft²:
$ 0.21</td><td>Est. Coating Life:
10-15 years</td></tr>
<tr><td>VOC:
☒ Yes 275 g/L
☐ No</td><td colspan="3">Product Hazard Ranking and Rationale:
Medium: The toxicity and exposure risks are Medium resulting in an overall Medium Hazard risk</td></tr>
<tr><td>Recommended Surface Prep:
Minimum: SSPC-SP3
Preferred: SSPC-SP6
Anchor profile: 1.5-2.5 mils
Recommended Pretreatment:
Surface must be clean and dry. Employ adequate methods to remove dirt, oil and all other contaminants that could interfere with adhesion.</td><td colspan="2">Advantages:
• No HAPs or hazardous materials
• Pot Life – 8 hrs @ 75 °F
• Excellent weatherability and gloss/color retention
• Excellent abrasion resistance
• Compatible with inorganic zinc rich primers, epoxies, etc.</td><td>Disadvantages:
•
•</td></tr>
<tr><td>Applicable Substrates:
☒ Aluminum
☒ Carbon Steel
☒ Stainless Steel</td><td colspan="3">Manufacturer Recommended Coating System:
• Inorganic Zinc Primer: Carboline Carbozinc 11HS (VOC: 479 g/L)
• Intermediate: Carboguard 893 (VOC: 195 g/L)</td></tr>
<tr><td colspan="3">Comments:

Include in testing</td><td>Recommended For Testing:
☒ Yes
☐ No</td></tr>
</table>

Table 3-5 Hempel Hempaxane 55000

Material	Material Description:	Estimated Cost Factors	Manufacturer
Name: Hempaxane 55000	This product is an epoxy polysiloxane hybrid. A glossy decorative and protective finishing coat for new steel structures in severely corrosive atmospheric environments. Base 55009 with curing Agent 98000.	**Unit Cost:** $	HEMPEL Coatings, Inc. 600 Conroe Park North Drive Conroe, TX 77303 (800) 678-6641
EPCRA: ☐ Yes ☐ No **Material:**		**Unit Size:** 1 gallon	
CERCLA: ☐ Yes ☐ No **Material:**		**Est. Coverage @ 3 mils DFT:** 455 sq ft/gal	
HAPS: ☐ Yes ☐ No **Material:**		**Est. Material Cost Per Ft^2:** $	**Est. Coating Life:**
VOC: ☒ **Yes 160 g/L** ☐ No	**Product Hazard Ranking and Rationale:**		
Recommended Surface Prep:	**Advantages:** • Low VOC content	**Disadvantages:** • For new steel structures • Pot Life – 3hrs @ 68 °F	
Recommended Pretreatment:			
Applicable Substrates: ☒ Aluminum ☒ Carbon Steel ☒ Stainless Steel	**Manufacturer Recommended Coating System:**		
Comments: **REMOVED FROM FURTHER CONSIDERATION BECAUSE THE PRODUCT IS NOT AVAILABLE IN U.S.A.**			**Recommended For Testing:** ☐ Yes ☒ **No**

Table 3-6 IPI-Superbarrier™ Interpenetrating Polymer Network

Material	**Material Description:**	**Estimated Cost Factors**	**Manufacturer**
Name: IPI-Superbarrier™ Interpenetrating Polymer Network	Inter Penetrating Networks ("IPN"s) family of products manufactured by Integrated Polymer Industries, Inc ("IPI").	**Unit Cost:** $	Integrated Polymer Industries, Inc 3029 S Harbor Blvd Santa Ana, CA 92704-6448 (714) 434-0800
EPCRA: ☐ Yes ☒ **No** **Material:**		**Unit Size:** 1 gallon kit	
CERCLA: ☐ Yes ☒ **No** **Material:**		**Est. Coverage @ 3 mils DFT:**	
HAPS: ☐ Yes ☒ **No** **Material:**		**Est. Material Cost Per Ft^2:** $	**Est. Coating Life:** Indefinite
VOC: ☐ Yes ☒ **No** **Zero VOC**	**Product Hazard Ranking and Rationale:** **Low:** No solvents; no fire or explosion risk; no breathing fumes or volatiles risk; no air, water, or environmental pollution risk; zero waste		
Recommended Surface Prep: Abrasive Blasting **Recommended Pretreatment:** No Pretreatment	**Advantages:** • No VOC's, HAP's, or HAZMAT's • No pretreatments required, one coating • Quick drying; Long shelf life • Standard spray equipment can be used • Rapid manual field repairs practical • Extreme resistance to corrosion, chemical attack	**Disadvantages:** • Application requires Standard Plural Component Spray Equipment • Difficult to remove due to adhesive/ cohesive bond strength (but can be recoated without having to remove the old coat) • Costlier than paints (but more cost effective due to IPN's durability)	
Applicable Substrates: ☒ Aluminum ☒ Carbon Steel ☒ Stainless Steel	**Manufacturer Recommended Coating System:** • None. Single application system.		
Comments: **REMOVED FROM FURTHER CONSIDERATION DUE TO PERFORMANCE IN AN AIR FORCE PROJECT**			**Recommended For Testing:** ☐ Yes ☒ **No**

Table 3-7 Integrated Polymer Ind. IPN—FlexFair 166501

Material	**Material Description:**	**Estimated Cost Factors**	**Manufacturer**
Name: IPN—FlexFair™ 166501 Interpenetrating Polymer Network	Inter Penetrating Networks ("IPN"s) family of products manufactured by Integrated Polymer Industries, Inc ("IPI"). Two-component, stiff paste, designed as a structural multi-purpose fairing compound with superior LO properties.	**Unit Cost:** $	Integrated Polymer Industries, Inc 3029 S Harbor Blvd Santa Ana, CA 92704-6448 (714) 434-0800
EPCRA: ☐ Yes ☒ **No** **Material:**		**Unit Size:** 1 gallon	
CERCLA: ☐ Yes ☒ **No** **Material:**		**Est. Coverage @ 3 mils DFT:** 12.8 sq ft/gal	
HAPS: ☐ Yes ☒ **No** **Material:**		**Est. Material Cost Per Ft^2:** $	**Est. Coating Life:** Indefinite
VOC: ☐ Yes ☒ **No** **Zero VOC**	**Product Hazard Ranking and Rationale:** **Low:** No solvents; no fire or explosion risk; no breathing fumes or volatiles risk; no air, water, or environmental pollution risk; zero waste		
Recommended Surface Prep: Abrasive Blasting **Recommended Pretreatment:** No Pretreatment	**Advantages:** • No VOC's, HAP's, or HAZMAT's • No pretreatments required, one coating • Quick drying; insensitive to moisture • Rapid manual field repairs practical • Extreme resistance to corrosion, chemical attack	**Disadvantages:** • Applied with a spatula • Pot Life – 50 min @ 77 °F • Difficult to remove due to bond strength (but can be recoated without having to remove the old coat) • Costlier than paints (but more cost effective due to IPN's durability	
Applicable Substrates: ☒ Aluminum ☒ Carbon Steel ☒ Stainless Steel	**Manufacturer Recommended Coating System:** • None. Single application system.		
Comments: **REMOVED FROM FURTHER CONSIDERATION DUE TO PERFORMANCE IN AN AIR FORCE PROJECT**			**Recommended For Testing:** ☐ Yes ☒ **No**

Table 3-8 International Protective Coatings Interfine 878

Material	Material Description:	Estimated Cost Factors	Manufacturer
Name: Interfine 878 Polysiloxane	This product is a polysiloxane. A high performance, two component, high solids finish which compliant with current VOC regulations, and exhibits superior gloss and color retention.	**Unit Cost:** $ 119.12	International Protective Coatings 6001 Antoine Dr Houston, TX 77091 (800) 589-1267
EPCRA: ☒ **Yes** ☐ No **Material:** Methyl alcohol; isopropyl alcohol; xylenes; barium sulfate; ethyl benzene; aluminum oxide; propylene glycol monomethyl ether acetate		**Unit Size:** 1 gallon	
CERCLA: ☒ **Yes** ☐ No **Material:** Ethyl benzene		**Est. Coverage @ 3 mils DFT:** 385 sq ft/gal	
HAPS: ☒ **Yes** ☐ No **Material:** Ethyl benzene		**Est. Material Cost Per Ft^2:** $ 0.31	**Est. Coating Life:** 20+ years
VOC: ☒ **Yes** **246 g/L** ☐ No	**Product Hazard Ranking and Rationale:** **Medium:** The toxicity ranking is Medium-Low and the exposure risk is Medium resulting in an overall Hazard ranking of Medium.		
Recommended Surface Prep: Abrasive Blasting (SSPC-SP6) Mechanical Removal (SSPC-SP11)	**Advantages:** • High gloss and color retention • Good flexibility and abrasion resistance • Compatible with inorganic zinc rich primers, epoxies, etc.	**Disadvantages:** • Pot Life – 2 hrs @ 77 °F	
Recommended Pretreatment: All surfaces should be clean, dry and free from contamination.			
Applicable Substrates: ☒ Aluminum ☒ Carbon Steel ☒ Stainless Steel	**Manufacturer Recommended Coating System:** • Carbon Steel: – Inorganic Zinc Primer: Interzinc 22HS (VOC: 340 g/L) – Intermediate: High-build epoxy Interseal 670HS (VOC: 240 g/L) • Aluminum and Stainless Steel: Only requires Interseal 670HS		
Comments: **Include in testing**			**Recommended For Testing:** ☒ **Yes** ☐ No

Table 3-9 International Protective Coatings Interfine 979

Material	Material Description:	Estimated Cost Factors	Manufacturer
Name: Interfine 979 Polysiloxane	This product is an epoxy polysiloxane hybrid. A high performance, two-component, high solids inorganic hybrid finish which offers compliance with all current VOC legislation and is free from isocyanates.	**Unit Cost:** $ 119.12	International Protective Coatings 6001 Antoine Dr Houston, TX 77091 (800) 589-1267
EPCRA: ☒ **Yes** ☐ No **Material:** Aluminum oxide; barium sulfate; isopropyl alcohol; propylene glycol monoethyl ether acetate		**Unit Size:** 1 gallon	
CERCLA: ☐ Yes ☒ **No** **Material:**		**Est. Coverage @ 3 mils DFT:** Product requires 4-6 mils thickness resulting in 244 sq ft/gal at 5 mils	
HAPS: ☐ Yes ☒ **No** **Material:**		**Est. Material Cost Per Ft^2:** $ 0.49 at 5 mils	**Est. Coating Life:** 20+ years
VOC: ☒ **Yes** **165 g/L** ☐ No	**Product Hazard Ranking and Rationale:** **Medium-Low:** While the exposure ranking is Medium, the toxicity is Low resulting in an overall Hazard ranking of Medium-Low		
Recommended Surface Prep: Abrasive Blasting (SSPC SP-6) Mechanical Removal (SSPC SP-11) **Recommended Pretreatment:** All surfaces should be clean, dry and free from contamination.	**Advantages:** • Low VOC content • Excellent gloss and color retention • Compatible with inorganic zinc rich primers, epoxies, etc.	**Disadvantages:** • Pot Life – 2 hrs @ 77 °F • Recoat interval – 10 to 14 days	
Applicable Substrates: ☒ Aluminum ☒ Carbon Steel ☒ Stainless Steel	**Manufacturer Recommended Coating System:** • Carbon Steel: - Inorganic Zinc Primer: Interzinc 22HS (VOC: 340 g/L) - Intermediate: High-build epoxy Interseal 670HS (VOC: 240 g/L) • Aluminum and Stainless Steel: Only requires Interseal 670HS		
Comments: **Include in testing**			**Recommended For Testing:** ☒ **Yes** ☐ No

Table 3-10 Jotun Jotacote PSO

Material	**Material Description:**	**Estimated Cost Factors**	**Manufacturer**
Name: Jotacote PSO Polysiloxane Topcoat	A two-pack epoxy polysiloxane topcoat with excellent gloss and color retention.	**Unit Cost:**	Jotun Paints (Europe) Ltd.
EPCRA: ☐ Yes ☒ **No** **Material:**		**Unit Size:** 1 gallon	
CERCLA: ☐ Yes ☐ No **Material:**		**Est. Coverage @ 3 mils DFT:**	
HAPS: ☒ **Yes** ☐ No **Material:** Xylene, ethyl benzene		**Est. Material Cost Per Ft^2:**	**Est. Coating Life:**
VOC: ☐ Yes ☐ No	**Product Hazard Ranking and Rationale:**		
Recommended Surface Prep:	**Advantages:**	**Disadvantages:**	
Recommended Pretreatment: No Pretreatment			
Applicable Substrates: ☒ Aluminum ☒ Carbon Steel ☒ Stainless Steel	**Manufacturer Recommended Coating System:**		
Comments: **REMOVED FROM FURTHER CONSIDERATION BECAUSE THE PRODUCT IS NOT AVAILABLE IN U.S.A.**			**Recommended For Testing:** ☐ Yes ☒ **No**

Table 3-11 Keeler & Long Megaflon

Material	**Material Description:**	**Estimated Cost Factors**	**Manufacturer**
Name: Megaflon MS Clearcoat 30	A fluoropolymer coating that provides excellent weatherability and chemical resistance.	**Unit Cost:**	Keeler & Long/PPG Industries, Inc. 856 Echo Lake Rd Watertown, CT 06795 (800) 238-8596
EPCRA: ☒ **Yes** ☐ No **Material:** Part A: Xylene, 1,2,4-trimethyl benzene, ethyl benzene		**Unit Size:**	
CERCLA: ☐ Yes ☐ No **Material:**		**Est. Coverage @ 3 mils DFT:**	
HAPS: ☒ **Yes** ☐ No **Material:** Xylene, ethyl benzene		**Est. Material Cost Per Ft^2:**	**Est. Coating Life:** years
VOC: ☐ Yes ☐ No	**Product Hazard Ranking and Rationale:**		
Recommended Surface Prep:	**Advantages:**	**Disadvantages:**	
Recommended Pretreatment: No Pretreatment			
Applicable Substrates: ☒ Aluminum ☒ Carbon Steel ☒ Stainless Steel	**Manufacturer Recommended Coating System:**		
Comments: **REMOVED FROM FURTHER CONSIDERATION BECAUSE THE PRODUCT CONTAINS ISOCYANATES**			**Recommended For Testing:** ☐ Yes ☒ **No**

Table 3-12 Kimetsan AquaSurTech (AST) D45-AMS

Material	**Material Description:**	**Estimated Cost Factors**	**Manufacturer**
Name: Kimetsan AquaSurTech (AST) D45-AMS	A two part waterborne coating that has low VOC and hazardous material content.	**Unit Cost:** $ 250.00	AquaSurTech Coating Products, N.A. 1006, rue de la Montagne, Suite #100 Montreal, Quebec H3G 1Y7 (514) 935-4415
EPCRA: ☒ **Yes** ☐ No **Material:** Tuluol (toluene)		**Unit Size:** 1 gallon	
CERCLA: ☒ **Yes** ☐ No **Material:** Tuluol (toluene)		**Est. Coverage @ 3 mils DFT:** Manufacturer recommends 1.5 mils resulting in 500 sq ft/gal	
HAPS: ☒ **Yes** ☐ No **Material:** Tuluol (toluene)		**Est. Material Cost Per Ft^2:** $ 0.50	**Est. Coating Life:** 20+ years
VOC: ☒ **Yes** **150 g/L** ☐ No	**Product Hazard Ranking and Rationale:** **Medium-High:** While the exposure ranking is High, the toxicity is Medium resulting in an overall Hazard ranking of Medium-High		
Recommended Surface Prep: Abrasive Blasting	**Advantages:** • Low VOC content • No Intermediate coating required • Pot Life – 6-8 hours depending on ambient conditions	**Disadvantages:** • High cost • Concerns about difficulty in application	
Recommended Pretreatment: AST Decontaminator			
Applicable Substrates: ☒ Aluminum ☒ Carbon Steel ☒ Stainless Steel	**Manufacturer Recommended Coating System:** • Wash: AST Decontaminator • Primer: AST Aquaprimer (VOC: 150 g/L)		
Comments: **Include in testing**			**Recommended For Testing:** ☒ **Yes** ☐ No

Table 3-13 Revodyne Industrial Coating

Material	**Material Description:**	**Estimated Cost Factors**	**Manufacturer**
Name: Revodyne Industrial Coating 716 5141	This is a complex polymer polyester resin. The catalyst used is Witco Co. #90 high point catalyst.	**Unit Cost:**	Revodyne Industrial Coatings 3700 Campus Drive, Suite 105 Newport Beach, CA 92660 949-581-8897
EPCRA: ☐ Yes ☐ No **Material:**		**Unit Size:** 5 gallon	
CERCLA: ☐ Yes ☐ No **Material:**		**Est. Coverage @ 3 mils DFT:** 250 sq ft/gal	
HAPS: ☐ Yes ☐ No **Material:**		**Est. Material Cost Per Ft^2:**	**Est. Coating Life:** 5-6 years
VOC: ☐ Yes ☐ No	**Product Hazard Ranking and Rationale:**		
Recommended Surface Prep: None **Recommended Pretreatment:** No Pretreatment	**Advantages:** • High solids content • No Primer or Intermediate coating required (can be applied direct-to-metal) • Compatible with inorganic zinc • Abrasion resistant	**Disadvantages:** • New material with no MSDS available	
Applicable Substrates: ☒ Aluminum ☒ Carbon Steel ☒ Stainless Steel	**Manufacturer Recommended Coating System:**		
Comments: **REMOVED FROM FURTHER CONSIDERATION BECAUSE A MSDS IS NOT AVAILABLE**			**Recommended For Testing:** ☐ Yes ☒ **No**

Table 3-14 Sherwin Williams Centurion

Material	Material Description:	Estimated Cost Factors	Manufacturer
Name: Centurion Water-based Urethane	This product is a VOC compliant, water based, polyester urethane enamel. It is a high gloss, abrasion resistant urethane with excellent weathering properties.	**Unit Cost:** $ 56.00	The Sherwin Williams Co 101 Prospect Ave N.W. Cleveland, OH 44115 (216) 566-2902
EPCRA: ☐ Yes ☒ **No** **Material:**		**Unit Size:** 1 gallon	
CERCLA: ☐ Yes ☒ **No** **Material:**		**Est. Coverage @ 3 mils DFT:**	
HAPS: ☐ Yes ☒ **No** **Material:**		**Est. Material Cost Per Ft^2:**	**Est. Coating Life:** years
VOC: ☒ **Yes** **66 g/L** ☐ No	**Product Hazard Ranking and Rationale:**		
Recommended Surface Prep:	**Advantages:** • Low VOC content • No HAPS or HAZMATs • High Gloss • Excellent weathering properties	**Disadvantages:** • Low isocyanate levels • Two part coating • Pot Life – 2 hrs @ 77 °F	
Recommended Pretreatment: Zinc Phosphate			
Applicable Substrates: ☒ Aluminum ☒ Carbon Steel ☒ Stainless Steel	**Manufacturer Recommended Coating System:** • None. Single application system.		
Comments: **REMOVED FROM FURTHER CONSIDERATION BECAUSE THE PRODUCT CONTAINS ISOCYANATES**			**Recommended For Testing:** ☐ Yes ☒ **No**

Table 3-15 Sherwin Williams Fast Clad HB Acrylic

Material	Material Description:	Estimated Cost Factors	Manufacturer
Name: Fast Clad HB Acrylic B66-410 Series	A one component, fast dry, high build finish designed for one coat application directly to organic or inorganic zinc-rich primers. Achieves superior gloss and color retention, fast drying, and low odor.	**Unit Cost:** $ 27.00	The Sherwin Williams Co 101 Prospect Ave N.W. Cleveland, OH 44115 (216) 566-2902
EPCRA: ☒ **Yes** ☐ No **Material:** Glycol ethers		**Unit Size:** 1 gallon	
CERCLA: ☐ Yes ☒ **No** **Material:**		**Est. Coverage @ 3 mils DFT:** Product recommends 8 mils thickness resulting in 85 sq ft/gal	
HAPS: ☒ **Yes** ☐ No **Material:** Glycol ethers		**Est. Material Cost Per Ft^2:** $ 0.32 at 8 mils	**Est. Coating Life:** 5-7 years
VOC: ☒ **Yes 164 g/L** ☐ No	**Product Hazard Ranking and Rationale:** **Low:** A Low Hazard ranking was given because no constituents were found to have any serious health concerns for workers		
Recommended Surface Prep: Minimum: SSPC-SP2 Preferred: SSPC-SP6	**Advantages:** • Low VOC content • No Intermediate coating required • Single component • Achieves a high film build in a single coat • Compatible with inorganic zinc rich primers, epoxies, etc.	**Disadvantages:** • Cannot be used on Stainless Steel without adhesion promoter (DTM Wash Primer recommended)	
Recommended Pretreatment: SSPC-SP1: Surface must be clean, dry and in sound condition. Remove all oil, dust, grease, dirt, loose rust, and other foreign material to ensure adequate adhesion.			
Applicable Substrates: ☒ Aluminum ☒ Carbon Steel ☒ Stainless Steel (only with adhesion promoter)	**Manufacturer Recommended Coating System:** • Inorganic Zinc Primer: SW ZincClad 11 (water-based) (VOC: 163 g/L)		
Comments: **Include in testing**			**Recommended For Testing:** ☒ **Yes** ☐ No

<table>
<tr><th colspan="4">Table 3-16 Sherwin Williams Polysiloxane XLE</th></tr>
<tr><th>Material</th><th>Material Description:</th><th>Estimated Cost Factors</th><th>Manufacturer</th></tr>
<tr><td>Name: Polysiloxane XLE Polysiloxane

EPCRA: ☒ Yes ☐ No
Material: Ethyl benzene, xylene

CERCLA: ☒ Yes ☐ No
Material: Ethyl benzene, xylene

HAPS: ☒ Yes ☐ No
Material: Ethyl benzene, xylene</td><td>This product is an epoxy polysiloxane hybrid.

A high performance, two component, high solids epoxy siloxane that combines the properties of both a high performance epoxy and polyurethane in one coat, but is free from isocyanates.</td><td>Unit Cost:
$ 110.00
Unit Size:
1 gallon
Est. Coverage @ 3 mils DFT:
Product requires two coats of 3-7 mils thickness resulting in 103-240 sq ft/gal
Est. Material Cost Per Ft²:
$ 0.46 for 2 coats at 3 mils
($1.07 for 2 coats at 7 mils)</td><td>The Sherwin Williams Co
101 Prospect Ave N.W.
Cleveland, OH 44115
(216) 566-2902

Est. Coating Life:
8-10 years</td></tr>
<tr><td>VOC:
☒ Yes 101 g/L
☐ No</td><td colspan="3">Product Hazard Ranking and Rationale:
Medium: Both the toxicity and exposure risks were ranked as Medium resulting in an overall Medium Hazard ranking</td></tr>
<tr><td>Recommended Surface Prep:
Minimum: SSPC-SP6
Preferred: SSPC-SP10
Anchor profile: 2.0 mil
Recommended Pretreatment:
SSPC-SP1: Surface must be clean, dry and in sound condition. Remove all oil, dust, grease, dirt, loose rust, and other foreign material to ensure adequate adhesion.</td><td colspan="2">Advantages:
• Self Priming
• Low VOC content
• Long Shelf life – 12 months, unopened
• Compatible with inorganic zinc rich primers, epoxies, etc.</td><td>Disadvantages:
• Cannot be used on Stainless Steel without adhesion promoter (DTM Wash Primer recommended)
• Pot Life – 4 hrs @ 77 °F
• Flash point = 80 °F
• Requires 2 coats of 3-7 mils thickness making it more expensive</td></tr>
<tr><td>Applicable Substrates:
☒ Aluminum
☒ Carbon Steel
☒ Stainless Steel (only with adhesion promoter)</td><td colspan="3">Manufacturer Recommended Coating System:
• Inorganic Zinc Primer: SW ZincClad 11 (water-based) (VOC: 163 g/L)</td></tr>
<tr><td colspan="3">Comments:

Include in testing</td><td>Recommended For Testing:
☒ Yes
☐ No</td></tr>
</table>

<table>
<tr><th colspan="5">Table 3-17 Sherwin Williams Sher-Cryl™ HPA</th></tr>
<tr><th>Material</th><td rowspan="4">Material Description:

An ambient cured, one component acrylic coating with superior exterior performance properties.</td><th colspan="2">Estimated Cost Factors</th><th>Manufacturer</th></tr>
<tr><td>Name: Sher-Cryl™ HPA High Performance Acrylic
EPCRA: ☒ Yes ☐ No
Material: Glycol ethers</td><td colspan="2">Unit Cost:
$ 28.49
Unit Size:
1 gallon</td><td rowspan="2">The Sherwin Williams Co
101 Prospect Ave N.W.
Cleveland, OH 44115
(216) 566-2902</td></tr>
<tr><td>CERCLA: ☒ Yes ☐ No
Material: Glycol ethers</td><td colspan="2">Est. Coverage @ 3 mils DFT:
Product recommends 2 coats at 3 mils thickness resulting in 125 sq ft/gal</td></tr>
<tr><td>HAPS: ☒ Yes ☐ No
Material: Glycol ethers</td><td colspan="2">Est. Material Cost Per Ft^2:
$ 0.23 for 2 coats at 3 mils</td><td>Est. Coating Life:
5-7 years</td></tr>
<tr><td>VOC:
☒ Yes 200 g/L
☐ No</td><td colspan="4">Product Hazard Ranking and Rationale:
Low: A Low Hazard ranking was given because no constituents were found to have any serious health concerns for workers.</td></tr>
<tr><td>Recommended Surface Prep:
Minimum: SSPC-SP2
Preferred: SSPC-SP6

Recommended Pretreatment:
SSPC-SP1: Surface must be clean, dry and in sound condition. Remove all oil, dust, grease, dirt, loose rust, and other foreign material to ensure adequate adhesion.</td><td colspan="2">Advantages:
• Low VOC content
• Single component
• No Intermediate coating required
• Compatible with inorganic zinc rich primers, epoxies, etc.</td><td colspan="2">Disadvantages:
• Cannot be used on Stainless Steel without adhesion promoter (DTM Wash Primer recommended)</td></tr>
<tr><td>Applicable Substrates:
☒ Aluminum
☒ Carbon Steel
☒ Stainless Steel (only with adhesion promoter)</td><td colspan="4">Manufacturer Recommended Coating System:
• Inorganic Zinc Primer: SW ZincClad 11 (water-based) (VOC: 163 g/L)</td></tr>
<tr><td colspan="4">Comments:

Include in testing</td><td>Recommended For Testing:
☒ Yes
☐ No</td></tr>
</table>

Table 3-18 Tego Silikoftal ED

Material	**Material Description:**	**Estimated Cost Factors**	**Manufacturer**
Name: Silikoftal ED Epoxy-siloxane Resin	An epoxy-siloxane resin that provides excellent gloss retention, weather resistance, and corrosion resistance.	**Unit Cost:**	Tego Chemie Service 1-800-446-1809
EPCRA: ☐ Yes ☐ No **Material:**		**Unit Size:**	
CERCLA: ☐ Yes ☐ No **Material:**		**Est. Coverage @ 3 mils DFT:**	
HAPS: ☐ Yes ☐ No **Material:**		**Est. Material Cost Per Ft^2:**	**Est. Coating Life:**
VOC: ☐ Yes ☐ No	**Product Hazard Ranking and Rationale:**		
Recommended Surface Prep:	**Advantages:**	**Disadvantages:**	
Recommended Pretreatment: No Pretreatment			
Applicable Substrates: ☐ Aluminum ☐ Carbon Steel ☐ Stainless Steel	**Manufacturer Recommended Coating System:**		
Comments: **THIS PRODUCT REMOVED FROM FURTHER CONSIDERATION BECAUSE IT IS NOT A COATING, BUT A RESIN THAT MUST BE INCORPORATED INTO A COATING (IT IS PART OF SHERWIN WILLIAMS' POLYSILOXANE XLE)**			**Recommended For Testing:** ☐ Yes ☒ No

4. PROCESS DESCRIPTIONS FOR VIABLE ALTERNATIVES

This project's purpose is to find isocyanate-free alternatives, therefore; a Waterborne Urethane (Sherwin Williams Centurion) and the Fluorourethanes (Carboline Carboxane 950 and Keeler & Long Megaflon) were removed from further consideration because they still contain isocyanates.

During the initial screening, it was found that two (2) of the products, Hempel Hempaxane 55000 and Jotun Jotacote PSO, currently are not commercially available in the United States and were therefore dropped from further consideration. It was also found that the Tego Silikoftal ED is only a resin that must be incorporated into a coating. The Tego resin is part of the Sherwin Williams Polysiloxane XLE that is to undergo testing.

The Inter Penetrating Networks (IPN) products (Integrated Polymer Industries IPI-Superbarrier and Integrated Polymer Industries IPN-FlexFair) were dropped from further consideration based on problems encountered during a previous project. The Air Force considered IPNs during a project to identify coatings for Intercontinental Ballistic Missiles (ICBMs). The IPNs were dropped due to failing an initial screening test (Pot Life) and issues of highly exothermic reactions causing smoke and heat (Logistics Environmental Office Pollution Prevention Project document *Air Force Potential Alternative Report, ZHTV02W147, Low/No-VOC Corrosion-preventive Coatings for ICBM Missile Support Equipment—Phase 1*, dated June 4, 2003; prepared by ITB under GSA Contract GS05T02BMM1604, Order Number 5TS5702D294).

The Revodyne Industrial Coating does not yet have a Material Safety Data Sheet (MSDS) available for ESOH analysis and as required for storage at NASA facilities and was therefore removed from further consideration under this project.

Ameron PSX 700 has been approved of and used in limited applications at both Kennedy Space Center (KSC) and Stennis Space Center (SSC) and will not be considered under this project.

The remaining identified alternatives were grouped together either as a Two Coating System or a Three Coating System as shown in Table 4-1 below.

Table 4-1 Alternatives Identified as Two or Three Coating System

Two Coating System	Kimetsan AST D45-AMS
	Sherwin Williams Fast Clad HB
	Sherwin Williams Polysiloxane XLE
	Sherwin Williams SHER-CRYL HPA
Three Coating System	Ameron PSX 1001
	Carboline Carboxane 2000
	Int'l Protective Coatings Interfine 878
	Int'l Protective Coatings Interfine 979

Surface preparation and Marking/Stenciling have not been included in these analyses because neither should significantly change from the current painting process (refer to Section 2.2.1. of this PAR for a description of the current surface preparation process).

4.1. Two Coating System

The Two Coating System eliminates the need for the intermediate epoxy primer coating thus resulting in lower emissions, less solid and liquid wastes, and less labor. The Two Coating Systems are:

- Kimetsan AST D45-AMS
- Sherwin Williams Fast Clad HB
- Sherwin Williams Polysiloxane XLE
- Sherwin Williams SHER-CRYL HPA

The Two Coating System process flow diagram is shown in Section 4.1.1. The Two Coating System process description and process equipment are described in Sections 4.1.2. and 4.1.3., respectively. Material usage and wastes and emissions are described in Sections 4.1.4. and 4.1.5., respectively. ESOH issues for each Two Coating System alternative are discussed in Section 5.

4.1.1. Process Flow Diagram

The Two Coating System process is same as the Baseline Process with the intermediate epoxy primer step removed. First, is surface preparation which is the same as the Baseline Process. Second, is the application of one or two coats of primer which are then cured. Finally, the parts are topcoated with the specified coating and cured. Markings are performed the same as the Baseline Process. The Two Coating System Process Flow Diagram is shown in Figure 4-1.

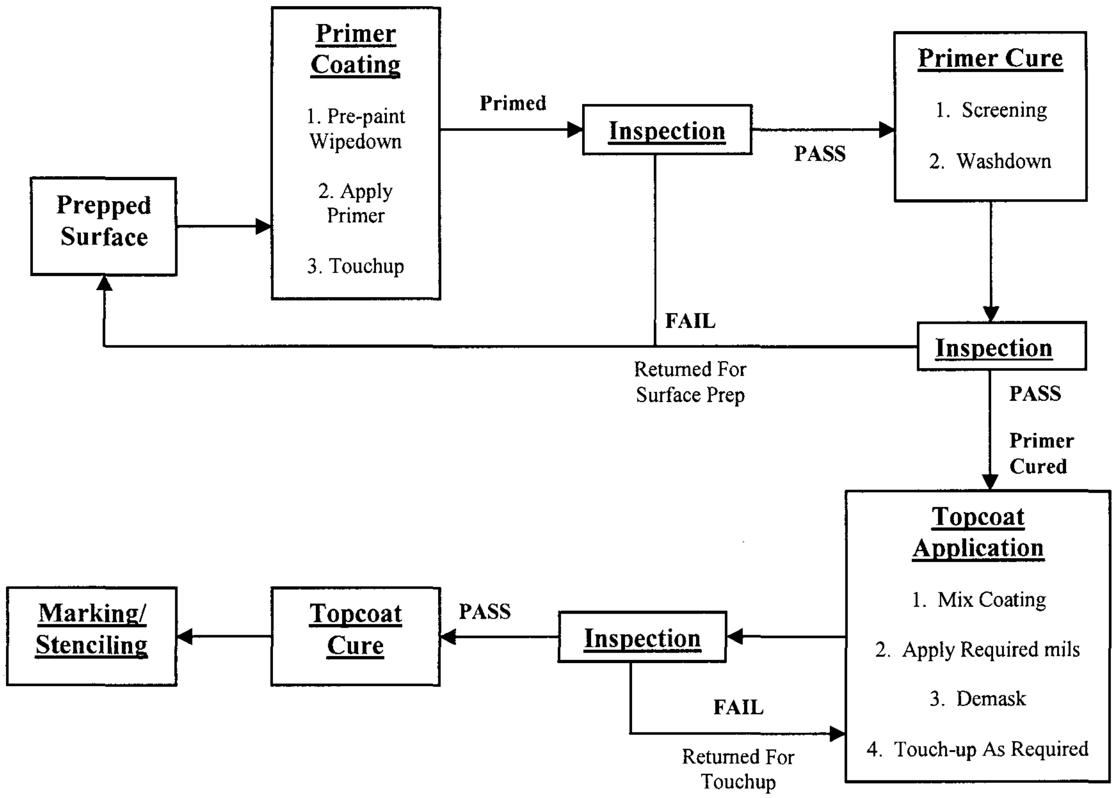
4.1.2. Process Description

The Two Coating System process description is the same as the Baseline process with the exception of the intermediate epoxy primer step that is not performed.

After the surface of the parts are properly prepared, normally a primer is mixed, strained, and allowed to stand for a period of time to allow the different components to react. The material is then thinned to the proper viscosity (if required) and applied by spraying with high volume low pressure (HVLP), electrostatic, or pressure feed paint spray equipment.

After priming, surfaces are allowed to cure. Only one wet coat of primer is typically applied to a surface; however, if an engineering drawing specifies more than one coat, then that number of primer coats is applied with air curing between each coat. Excessive primer build-up is normally avoided to prevent intercoat adhesion failures.

Figure 4-1 Process Flow Diagram for Two Coating System



To ensure freshly painted surfaces are not contaminated by dust and other particulate matter, painting areas are cleaned on a regular basis, with the cleaning interval dependent on usage. The painting operations debris such as over-spray materials, paint chips, abrasive media, rags, masking materials, paint strainers, floor covering paper, and leftover pre-catalyzed coatings are collected in drums and disposed of in accordance with the local, state, and federal requirements of the locations where the operations occurred.

After areas are sufficiently primed and cured, the topcoat is applied and then cured per the manufacturer's directions.

Spray guns are normally flushed with an approved coating solvent before each operator break and at the end of each shift. Unless captured, VOCs from equipment cleaning are vented to the atmosphere. Used solvents or thinners may be recycled if an appropriate distiller is available. Otherwise, the waste solvents or thinners are collected and disposed of in accordance with the local, state, and federal requirements for the locations where the operations occurred.

4.1.3. Process Equipment

All of the Two Coating System alternatives can be applied using conventional or airless spray, brush or roller.

4.1.4. Anticipated Material and Energy Usage

Anticipated changes in the annual material (excluding actual topcoat) and energy usage of the Two Coating System are shown in Table 4-2. Refer to Figure 4-2 for the process flow diagram.

Table 4-2 Two Coating System – Anticipated Changes in Material and Energy Usage

Process Step	Material/Energy
Primer Coating	Changes dependent upon material
Intermediate Epoxy Primer Coating	Epoxy primer no longer required
	Paint filters for intermediate epoxy primer step no longer required
	Lint free wipe cloths for intermediate epoxy primer step no longer required
	Appropriate epoxy solvent no longer required
	Energy required for intermediate epoxy primer step no longer required
	Labor required for intermediate epoxy primer step no longer required
Topcoating	Changes dependent upon material (See Table 4-3.)

Table 4-3 shows how many square feet per gallon each coating can cover at its recommended DFT and number of coatings. A lower amount of coverage means that more coating is required.

Table 4-3 Two Coating System – Coverage at Recommended Thickness

Coating	Recommended DFT	Coverage (sq ft/gal)
Kimetsan AST D45-AMS	1.5 mils	500
SW Fast Clad HB Acrylic	8 mils	85
SW Polysiloxane XLE	2 coats of average 5 mils	172
SW SHER-CRYL HPA	2 coats of 3 mils	125

4.1.5. Anticipated Wastes and Emissions

The anticipated changes in the quantities of liquid wastes, solid wastes and air emissions that are expected by converting to the two coating application process are shown in Table 4-3.

Table 4-4 Two Coating System – Anticipated Changes in Wastes and Emissions

Waste/Emission	Change from Current Process

Table 4-4 Two Coating System – Anticipated Changes in Wastes and Emissions	
Wastes	
Intermediate Epoxy Primer	No longer required
Rags, debris, and paint filters	Reduced by the amount required for intermediate epoxy primer step
Emissions	
VOC in Primer	Varies with each alternative
VOC in Intermediate Epoxy Primer	No longer released
VOC in Topcoat	Varies with each alternative (See Table 5-2 for side-by-side comparison)

4.2. Three Coating System

The Three Coating System is the same as the Baseline Process with a primer, an intermediate epoxy primer coat, and the topcoat. The Three Coating Systems are:

- Ameron PSX 1001
- Carboline Carboxane 2000
- IPC Interfine 878
- IPC Interfine 979

The Three Coating System process flow diagram, process description and process equipment are described in the same as the Baseline process. Process equipment is discussed in Section 4.2.3. Material usage and wastes and emissions are described in Sections 4.2.4. and 4.2.5., respectively. ESOH issues for each Three Coating System alternative are discussed in Section 5.

4.2.1. Process Flow Diagram

The Three Coating System Process Flow Diagram is the same as the Baseline process (See Figure 2-1).

4.2.2. Process Description

The Three Coating System Process Description is the same as the Baseline process (See Section 2.2).

4.2.3. Process Equipment

All of the Three Coating Process alternatives can be applied using conventional or airless spray, brush or roller.

4.2.4. Anticipated Material and Energy Usage

There are no anticipated large changes in annual material and energy usage with the Three Coating Process as compared to the Baseline Process. However, material and energy changes are dependent upon the coating.

Table 4-5 shows how many square feet per gallon each coating can cover at its recommended DFT and number of coatings. A lower amount of coverage means that more coating is required.

Table 4-5 Three Coating System – Coverage at Recommended Thickness

Coating	Recommended DFT	Coverage (sq ft/gal)
Ameron PSX 1001	3 mils	330
Carboline Carboxane 2000	3 mils	455
IPC Interfine 878	3 mils	385
IPC Interfine 979	5 mils	244

4.2.5. Anticipated Wastes and Emissions

There are no anticipated changes in the quantities of liquid or solid wastes by converting to the Three Coating Process. The anticipated changes in the quantities of air emissions that are expected by converting to the Three Coating Process vary according to product. A comparison of VOC contents is shown in Table 5-1.

5. PRELIMINARY ESOH ANALYSIS OF VIABLE ALTERNATIVES

As part of the selection of potential alternatives, the baseline material (Carboline) and each of the remaining alternatives were qualitatively assessed for associated ESOH concerns according to the procedures described in Appendix A. This initial assessment was conducted to compare the alternatives with the baseline material and determine whether there were any conspicuous ESOH issues that may need addressed when selecting alternatives for testing. Detailed results of the ESOH analysis of the baseline material and viable alternatives can be found in Appendix A. The results are summarized in Table 5-1. *(Extracted from the product MSDS)*

Environmental Issues

Each viable alternative was evaluated to determine the extent of its regulation under the major federal environmental laws. Based on the product MSDS, each alternative was evaluated using the following criteria:

- *Air Emissions per Clean Air Act (CAA)*
- *Solid/Hazardous Waste Generation per Resource Conservation and Recovery Act (RCRA)*
- *Reporting requirements per Section 313 of the Emergency Planning and Community Right-to-Know Act (EPCRA)*
- *Hazardous Substances per Comprehensive Environmental Response, Compensation and Liability Act (CERCLA)*

Health and Safety Issues

Each viable alternative was evaluated to determine concerns related to safety and occupational health issues. Not all product MSDS contained all of the categories listed below. Only those categories that applied for the specific product are listed on the product MSDS. Using the product MSDS, each alternative was evaluated using the following criteria:

- *Acute Effects (short term)*
- *Chronic Effects (long term)*
- *Inhalation*
- *Skin contact*
- *Eye contact*

Product	Topcoat VOC (g/L)	HAPs[a]	RCRA[a]	EPCRA[a]	CERCLA[a]	Ratings[b] Toxicity	Ratings[b] Exposure	Ratings[b] Hazard
Carboline Carbothane 134 HB (Baseline)	419	4	2	2	3	M	M-H	M-H
ICI Devoe Devthane 359 DTM (Baseline)	340	3	2	6	4	M	M-H	M-H
Ameron PSX 1001	384	3	1	6	5	M-L	M-H	M
Carboline Carboxane 2000	275	0	0	0	0	M	M	M
IPC Interfine 878	246	1	1	7	1	M-L	M	M
IPC Interfine 979	165	0	0	4	0	L	M	M-L
Kimetsan AST D45-AMS	150	1	1	1	1	M	H	M-H
SW Fast Clad HB Acrylic	164	1	0	1	0	L	L	L
SW Polysiloxane XLE	101	2	2	2	2	M	M	M
SW SHER-CRYL HPA	200	1	1	1	1	L	L	L

Table 5-1 Summary of ESOH Analysis for Viable Alternatives

a. Number of reportable constituents that are listed on the MSDS for a particular coating.
b. L = Low M = Medium H = High (Scoring derived from data reflected in the material MSDS, refer to Appendix A)

6. SUMMARY

During the coatings project, isocyanates in coatings currently used by NASA were identified as hazardous materials of concern, and targeted for elimination or reduction. Eighteen (18) alternative materials/processes were identified as potential replacements for topcoats containing isocyanates. These alternatives were identified through literature searches and direct vendor queries. The alternatives initially identified were:

- Ameron PSX 700
- Ameron PSX 1001
- Carboline Carboxane 950
- Carboline Carboxane 2000
- Hempel Hempaxane 55000
- Integrated Polymer Industries IPN-FlexFair
- Integrated Polymer Industries IPI-Superbarrier
- International Protective Coatings Interfine 878
- International Protective Coatings Interfine 979
- Jotun Jotacote PSO
- Keeler & Long Megaflon
- Kimetsan Limited AquaSurTech (AST) D45-AMS
- Revodyne Industries Industrial Coating
- Sherwin Williams Centurion
- Sherwin Williams Fast Clad HB Acrylic
- Sherwin Williams Polysiloxane XLE
- Sherwin Williams SHER-CRYL HPA
- Tego Sililoftal ED

Manufacturers and distributors of the identified alternatives were contacted, and technical, environmental, safety, and occupational health information about the alternatives was gathered and compared with the baseline process.

It was decided in stakeholder technical meetings that the goal of the AP2 effort was to identify an isocyanate-free coating as a replacement for currently used aliphatic isocyanate polyurethanes. Initially, the search for replacement materials or processes included all the identified alternatives to allow for the consideration of all possible new technologies.

Of the 18 identified alternatives, ten (10) were dropped from further consideration because they were not technically feasible or were not commercially available. Those products removed from further consideration were:

- Ameron PSX 700 (already has limited use at NASA and AFSPC installations)
- Carboline Carboxane 950 (contains isocyanates)
- Hempel Hempaxane 55000 (not available in the U.S.A.)
- Integrated Polymer Industries IPN-FlexFair (results of previous work conducted by Air Force)

- Integrated Polymer Industries IPI-Superbarrier (results of previous work conducted by Air Force)
- Jotun Jotacote PSO (not available in the U.S.A.)
- Keeler & Long Megaflon (contains isocyanates)
- Revodyne Industrial Coating
- Sherwin Williams Centurion (contains isocyanates)
- Tego Sililoftal ED

Material Safety Data Sheets and Product Information Sheets for those alternatives removed from further consideration in this project are provided in Appendix C. The remaining identified alternatives which were selected for testing were grouped into a Two Coating System or a Three Coating System as shown below:

Table 6-1 Alternatives Identified as Two or Three Coating System

Two Coating System	Kimetsan AST D45-AMS
	Sherwin Williams Fast Clad HB Acrylic
	Sherwin Williams Polysiloxane XLE
	Sherwin Williams SHER-CRYL HPA
Three Coating System	Ameron PSX 1001
	Carboline Carboxane 2000
	Int'l Protective Coatings Interfine 878
	Int'l Protective Coatings Interfine 979

Material Safety Data Sheets and Product Information Sheets for those alternatives selected for testing under this project are provided in Appendix B.

APPENDIX A

Environmental, Safety and Occupational Health Analyses For Viable Alternatives Selected for Testing

A.1. BACKGROUND OF ESOH ANALYSIS

As part of the down-selection of potential alternatives, each of the remaining viable alternatives was qualitatively assessed for associated Environmental, Safety and Occupational Health (ESOH) concerns. This initial assessment was conducted to determine whether there were any conspicuous ESOH issues that may need to be addressed.

A.1.1. Environmental Issues

The viable alternatives were evaluated to determine the extent of their regulation under the major federal environmental laws. Using available resources, each alternative was evaluated based on the criteria listed below.

- *Air Emissions:* Each of the identified constituents released to the air during the viable alternative process was analyzed to determine if it is regulated under the Clean Air Act (CAA) as a volatile organic compound (VOC) emission, a hazardous air pollutant (HAP), or an ozone-depleting substance (ODS).
- *Solid/Hazardous Waste Generation:* Each alternative was evaluated to determine whether solid waste is generated by the process, and if so, whether that waste may be regulated under Subtitle C of the Resource Conservation and Recovery Act (RCRA).
- *Reporting Requirements*: The viable alternatives were examined to determine whether any of the constituents are required to be listed on the Toxic Release Inventory (TRI) reports under Section 313 of the Emergency Planning and Community Right-to-Know Act (EPCRA).
- *CERCLA Hazardous Substances*: Each alternative was assessed to determine if its constituents are listed as hazardous substances under the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA).
- *Wastewater Discharges:* Each viable alternative was analyzed to determine whether its use would cause discharge of any wastewaters regulated under the Clean Water Act (CWA). However, all substances designated under CWA Section 307(a) and Section 311(b)(2)(A) are listed as CERCLA hazardous substances and are identified there.

The regulatory impacts of process alternatives are not easily compared, since it is impossible to say that a process that emits a hazardous waste sludge is any more or less desirable than a process that emits a HAP. Therefore, it is not possible to categorize each of the alternatives based on some type of regulatory ranking system. However, an alternative that has few leniently regulated constituents will clearly be preferable to one that has many stringently regulated constituents, so the extent to which an alternative is regulated may be considered as an element of the down-selection process.

A.1.2. Health & Safety Issues

Each viable alternative was evaluated to determine concerns related to safety and occupational health issues. Not all product MSDS contained all of the categories listed below. Only those categories that applied for the specific product are listed on the product

MSDS. Using the product MSDS, each alternative was evaluated using the following criteria:

- *Acute Effects (short term)*
- *Chronic Effects (long term)*
- *Inhalation*
- *Skin contact*
- *Eye contact*
- *Special Precautions*

Based on this information, each alternative was given a Toxicity Ranking and Exposure Ranking which were then used to calculate an overall Hazard Ranking as described below. The rankings represent an average hazard for all of the constituents for each coating system.

Toxicity Ranking: As part of the ESOH down-selection criteria, the viable alternatives were qualitatively assessed for evident hazards (i.e., toxicity and exposure). Toxicity was qualitatively reviewed, and each down-selected product was given a final toxicity ranking. Toxicity rankings of high, medium, and low were assigned to viable alternatives based on the analysis of available literature. Parameters reviewed included median lethal concentrations (LC_{50}) and/or median oral lethal doses (LD_{50}). The LC_{50} and LD_{50} describe the amount or concentration of compound that is estimated to be lethal to 50% of the animals in a test group under stated conditions (e.g., inhalation or oral exposure). The qualitative ranking scheme for alternative products is provided in Table A-1 below.

Table A-1 Toxicity Ranking for Alternative Products

Toxicity Ranking	Descriptive Term	LC_{50} (ppm)	LD_{50} Single Dose (per Kg Body Mass)
H	Highly Toxic	< 50	< 50 mg
M	Moderately Toxic	50-50,000	50 mg – 5 g
L	Relatively Nontoxic	> 50,000	> 5 g

Exposure Ranking: As ESOH hazard down-selection is a function of toxicity and exposure, a qualitative exposure ranking scheme is also provided. The procedure for establishing the exposure ranking scheme is discussed briefly below. Exposure can occur only when the potential exists for a receptor to directly contact released chemical constituents from the identified alternatives, or if there is a mechanism for released constituents to be transported to a receptor. Each component (released constituents, mechanism of transport, point of contact, and presence of a receptor) must be present for a complete exposure pathway to exist. Without exposure, there is no risk; therefore, the exposure assessment is a key element when assessing potential risks associated with a technology alternative. A reliable method of calculating exposure is by conducting a state-of-the-art risk assessment for the potential alternatives that have been identified to replace isocyanate containing coatings.

The exposure criteria used in the screening and ranking are the Occupational Safety and Health Administration (OSHA) promulgated Permissible Exposure Levels (PELs) and the American Conference of Governmental Industrial Hygienists' (ACGIH) Threshold Limit

Values (TLVs). Three exposure ranking levels and associated TLV and PEL intervals were chosen based on the ACGIH recommendations. The qualitative ranking scheme for alternative products is provided in Table A-2 below.

Table A-2 Exposure Ranking for Alternative Products

Toxicity Ranking	Descriptive Term	TLV and PEL Values
H	High Exposure Level	< 100 ppm
M	Moderate Exposure Level	100-500 ppm
L	Relatively No Exposure Level	> 500 ppm

If TLVs and PELs were not available, then a subjective interpretation of the available information on the compound was performed. Also, the exposure ranking takes into account the potential for toxic released constituents as well as the physical hazards of the compound (e.g., explosivity and corrosivity).

Hazard Ranking: A final hazard ranking designation was given to the viable alternatives based on toxicity and exposure ranking as described above. The hazard ranking is determined by the matrix provided in Table A-3 below.

Table A-3 Hazard Ranking Matrix

Exposure Ranking	Toxicity Ranking		
	High	***Medium***	***Low***
High	H	M-H	M
Medium	M-H	M	M-L
Low	M	M-L	L

**These judgments are based on available scientific information and are of a limited scope.

A.2. ESOH ANALYSIS OF BASELINE MATERIALS

The baseline materials for this project were Carboline Carbothane 134 HB and ICI Devoe Devthane 359 DTM from the approved products list contained in NASA Technical Standard NASA-STD-5008A, *Protective Coating of Carbon Steel, Stainless Steel, and Aluminum on Launch Structures, Facilities, and Ground Support Equipment*, dated January 21, 2004.

A.2.1. Environmental Issues

A.2.1(a) Carboline Carbothane 134 HB

- *Air Emissions per CAA:*
  - Xylene (Part A)
  - Ethyl benzene (Part A)
  - Butly acetate (Parts A and B)
  - Methyl ethyl ketone (Parts A and B)
  - Hexamethylene-1,6-diisocyanate (HDI Isocyanate) (Part B)
  - VOC content: 419 g/L
- *Solid/Hazardous Waste Generation per RCRA:*
  - Xylene (Part A)
  - Methyl ethyl ketone (Parts A and B)
- *EPCRA Reporting Requirements*:
  - Xylene (Part A)
  - Methyl ethyl ketone (Parts A and B)
  - Aromatic solvent (Part B)
- *CERCLA Hazardous Substances*:
  - Xylene (Part A)
  - Butyl acetate (Parts A and B)
  - Methyl ethyl ketone (Parts A and B)
  - Hexamethylene-1,6-diisocyanate (HDI Isocyanate) (Part B)

A.2.1(b) ICI Devoe Devthane 359 DTM

- *Air Emissions per CAA:*
  - Ethyl benzene
  - Xylene
  - Hexamethylene diisocyanate
  - VOC content: 340 g/L
- *Solid/Hazardous Waste Generation per RCRA:*
  - Ethyl benzene
  - Xylene
- *EPCRA Reporting Requirements*:
  - Ethyl benzene
  - Propylene glycol monomethyl ether
  - Xylene
  - Barium sulfate

    - 1,2,4-trimethylbenzene
    - Hexamethylene diisocyanate
- *CERCLA Hazardous Substances*:
    - Ethyl benzene
    - Butyl acetate
    - Xylene
    - Hexamethylene diisocyanate

A.2.2. Health & Safety Issues

A.2.2(a) Carboline Carbothane 134 HB

- *Acute Effects (short term)*
    - May cause dizziness, headache or nausea if inhaled
- *Chronic Effects (long term)*
    - Contains SILICA which can cause cancer
    - Reports have associate repeated and prolonged overexposure to solvent with permanent brain and nervous system damage
- *Inhalation*
    - Harmful if inhaled, may affect the brain or nervous system causing dizziness, headache or nausea
    - May cause nose and throat irritation
- *Skin contact*
    - May cause skin irritation
- *Eye contact*
    - May cause eye irritation
- *Special Precautions:*
    - Respiratory: Supplied-Air Respirator (SAR) or organic vapor/spray mist/mixing
    - Skin: Tyvek or other disposable coveralls; gloves/barrier cream recommended for exposed skin; safety shower or washing facility required
    - Eye: Full face respirator for spray application; splash goggles with faceshield when mixing components; eyewash required
- *Toxicity Ranking:* Medium
- *Exposure Ranking:* Medium-High
- *Hazard Ranking:* Medium-High

A.2.2(b) ICI Devoe Devthane 359 DTM

- *Acute Effects (short term)*
    - Contains a chemical that may be absorbed through skin
    - Free diisocyanate may cause allergic reaction in susceptible persons
- *Chronic Effects (long term)*
    - Possible human carcinogen (carbon black and ethyl benzene)
    - In a 2-year inhalation study conducted by the national toxicology program (NTP), ethyl benzene vapor at 750 ppm produced kidney and testicular tumors

in rats and lung and liver tumors in mice (the relevance of these results to humans is not known)
    - High exposure to xylene in some animal studies, often at maternally toxic levels, have affected embryo/fetal development (the significance of this finding to humans is not known)
    - Reports have associated repeated and prolonged overexposure to solvents with permanent brain and nervous system damage
- *Inhalation*
    - Irritation of respiratory tract
    - Possible sensitization to respiratory tract
    - Prolonged inhalation may lead to mucous membrane irritation, fatigue, drowsiness, dizziness and/or lightheadedness, headache, uncoordination, nausea, vomiting, chest pain, blurred vision, flu-like symptoms, coughing, difficulty with speech, central nervous system depression, anesthetic effect or narcosis, difficulty of breathing, allergic response, tremors, severe lung irritation or damage, liver damage, kidney damage, pneumoconiosis, loss of consciousness, respiratory failure, asphyxiation, death
- *Skin contact*
    - Irritation of skin
    - Possible sensitization to skin
    - Skin contact may result in dermal absorption of component(s) of this product which may cause drowsiness, dizziness and/or lightheadedness
    - Prolonged or repeated contact can cause dermatitis, defatting, blistering, severe skin irritation or burns
- *Eye contact*
    - Irritation of eyes
    - Prolonged or repeated contact can cause conjunctivitis, blurred vision, tearing of eyes, redness of eyes, severe eye irritation or buns, corneal injury
- *Special Precautions*
    - Respiratory: Supplied-Air Respirator (SAR) or organic vapor/spray mist/mixing
    - Skin: Tyvek or other disposable coveralls; gloves/barrier cream recommended for exposed skin; safety shower or washing facility required
    - Eye: Full face respirator for spray application; splash goggles with faceshield when mixing components; eyewash required
- *Toxicity Ranking:* Medium
- *Exposure Ranking:* Medium-High
- *Hazard Ranking:* Medium-High

A.3. ESOH ANALYSIS OF AMERON PSX 1001

A.3.1. Environmental Issues

- *Air Emissions per CAA:*
    - Xylene
    - Ethyl benzene
    - Toluene (trace contaminant)
    - VOC content: 384 g/L
- *Solid/Hazardous Waste Generation per RCRA:*
    - Xylene
- *EPCRA Reporting Requirements*:
    - Xylene
    - 1,2,4-trimethyl benzene
    - Ethyl benzene
    - Methanol (hydrolysis generated)
    - Benzene (trace contaminant)
    - Toluene (trace contaminant)
- *CERCLA Hazardous Substances*:
    - Xylene
    - Ethyl benzene
    - Methanol (hydrolysis generated)
    - Toluene (trace contaminant)
    - Proprietary ingredient

A.3.2. Health & Safety Issues

- *Acute Effects (short term)*
    - Irritating to eyes, skin, and if inhaled; to nose and throat
    - Excessive or prolonged inhalation can cause headache, nausea or dizziness
- *Chronic Effects (long term)*
    - Reports have associated repeated and prolonged overexposure to solvents with permanent brain and nervous system damage
- *Inhalation*
    - Irritant.
    - Lung injury.
    - Central nervous system damage.
    - Chemical pneumonia.
    - Xylene or toluene may cause irregular heart beat
- *Skin contact*
    - Irritant.
    - Burns.
    - Can be absorbed through skin.
    - Can cause defatting and drying of skin
- *Eye contact*
    - Sever irritant.

- Corneal injury.
- Irreversible buns and damage.
- Methanol, if swallowed, can cause eye damage and blindness

- *Special Precautions*
  - Respiratory: Air-Purifying Respiratory (APR)/Powered Air-Purifying Respirator (PAPR) for organic vapor/spray mist; Supplied-Air Respirator (SAR) for confined spaces
  - Skin: Tyvek or other disposable coveralls; gloves/barrier cream recommended for exposed skin; safety shower or washing facility required
  - Eye: Full face respirator for spray application; splash goggles with faceshield when mixing components; eyewash required
- *Toxicity Ranking:* Medium-Low
- *Exposure Ranking:* Medium-High
- *Hazard Ranking:* Medium

A.4. ESOH ANALYSIS OF CARBOLINE CARBOXANE 2000

A.4.1. Environmental Issues

- *Air Emissions per CAA:*
  - VOC content: 275 g/L
- *Solid/Hazardous Waste Generation per RCRA:*
  - NONE
- *EPCRA Reporting Requirements*:
  - NONE
- *CERCLA Hazardous Substances*:
  - NONE

A.4.2. Health & Safety Issues

- *Acute Effects (short term)*
  - Irritating to eyes, skin, and if inhaled; to nose and throat
  - If inhaled, may cause dizziness, headache, or nausea
- *Chronic Effects (long term)*
  - Reports have associated repeated and prolonged overexposure to solvents with permanent brain and nervous system damage
- *Inhalation*
  - Harmful if inhaled, may affect the brain or nervous system, causing dizziness, headache or nausea.
  - May cause nose and throat irritation
- *Skin contact*
  - Can cause skin burns
- *Eye contact*
  - Can cause eye burns
- *Special Precautions*
  - Respiratory: Air-Purifying Respiratory (APR)/Powered Air-Purifying Respirator (PAPR) for organic vapor/spray mist; Supplied-Air Respirator (SAR) for confined spaces
  - Skin: Tyvek or other disposable coveralls; gloves/barrier cream recommended for exposed skin; safety shower or washing facility required
  - Eye: Full face respirator for spray application; splash goggles with faceshield when mixing components; eyewash required
- *Toxicity Ranking:* Medium
- *Exposure Ranking:* Medium
- *Hazard Ranking:* Medium

A.5. ESOH ANALYSIS OF IPC INTERFINE 878

A.5.1. Environmental Issues

- *Air Emissions per CAA:*
  - Ethyl benzene (Base)
  - VOC content: 246 g/L
- *Solid/Hazardous Waste Generation per RCRA:*
  - Ethyl benzene (Base)
- *EPCRA Reporting Requirements*:
  - Methyl alcohol (Base)
  - Isopropyl alcohol (Base)
  - Propylene glycol monomethyl ether acetate (Base)
  - Xylenes (o-, m-, p- isomers) (Base)
  - Barium sulfate (Base)
  - Ethyl benzene (Base)
  - Aluminum Oxide (Base)
- *CERCLA Hazardous Substances*:
  - Ethyl benzene (Base)

A.5.2. Health & Safety Issues

Although the product says that it is isocyanate-free, a test of a bulk sample of 878 Light Base for isocyanates is recommended.

- *Acute Effects (short term)*
  - Irritating to eyes, skin, and if inhaled; to nose and throat (Parts A and B)
  - Vapors may affect the brain or nervous system causing dizziness, headache or nausea (Part A)
- *Chronic Effects (long term)*
  - Contains an ingredient which can cause organ damage (Part A)
  - Birth defect hazard (Part A)
  - Possible cancer hazard (Part A)
  - Cancer hazard (Part B)
  - Reports have associated repeated and prolonged overexposure to solvents with permanent brain and nervous system damage (Part B)
- *Inhalation*
  - May be harmful (Parts A and B) or fatal if inhaled (Part A)
  - Causes lung irritation (Part A)
  - Causes nose and throat irritation (Parts A and B)
- *Skin contact*
  - Causes skin irritation (Part A)
  - Causes skin burns (Part B)
  - May cause allergic skin reaction (Part A)
  - May be harmful if absorbed through the skin (Parts A and B)
- *Eye contact*

    - May cause blindness (Parts A and B)
- *Special Precautions*
    - Respiratory: Air-Purifying Respiratory (APR)/Powered Air-Purifying Respirator (PAPR) for organic vapor/spray mist (SAR if free isocyanates are present); Supplied-Air Respirator (SAR) for confined spaces
    - Skin: Tyvek or other disposable coveralls; gloves/barrier cream recommended for exposed skin; safety shower or washing facility required
    - Eye: Full face respirator for spray application; splash goggles with faceshield when mixing components; eyewash required
    - Contains water reactive/corrosive ingredients
- *Toxicity Ranking:* Medium-Low
- *Exposure Ranking:* Medium
- *Hazard Ranking:* Medium

A.6. ESOH ANALYSIS OF IPC INTERFINE 979

A.6.1. Environmental Issues

- *Air Emissions per CAA:*
    - VOC Content: 165 g/L
- *Solid/Hazardous Waste Generation per RCRA:*
    - NONE
- *EPCRA Reporting Requirements*:
    - Isopropyl alcohol (Base)
    - Aluminum oxide (Base)
    - Barium sulfate (Base)
    - Propylene glycol monoethyl ether acetate (Base)
- *CERCLA Hazardous Substances*:
    - NONE

A.6.2. Health & Safety Issues

Although the product says that it is isocyanate-free, a test of a bulk sample of 979 Light Base for isocyanates is recommended.

- *Acute Effects (short term)*
    - Irritating to eyes, skin, and if inhaled; to nose and throat (Base and Converter)
    - Vapors may affect the brain or nervous system causing dizziness, headache or nausea (Base and Converter)
- *Chronic Effects (long term)*
    - Contains an ingredient which can cause organ damage (Base)
    - Birth defect hazard (Base)
    - Possible cancer hazard (Base)
    - Cancer hazard (Converter)
    - Reports have associated repeated and prolonged overexposure to solvents with permanent brain and nervous system damage (Base and Converter)
- *Inhalation*
    - May be harmful (Base and Converter) or fatal if inhaled (Base)
    - Causes lung irritation (Base)
    - Causes nose and throat irritation (Base and Converter)
- *Skin contact*
    - Causes skin irritation (Base)
    - Causes skin burns (Converter)
    - May cause allergic skin reaction (Base)
    - May be harmful if absorbed through the skin (Base and Converter)
- *Eye contact*
    - Causes sever eye irritation (Base)
    - May cause blindness (Converter)
- *Special Precautions*

  - Respiratory: Air-Purifying Respiratory (APR)/Powered Air-Purifying Respirator (PAPR) for organic vapor/spray mist (SAR if free isocyanates are present); Supplied-Air Respirator (SAR) for confined spaces
  - Skin: Tyvek or other disposable coveralls; gloves/barrier cream recommended for exposed skin; safety shower or washing facility required
  - Eye: Full face respirator for spray application; splash goggles with faceshield when mixing components; eyewash required
  - Contains water reactive/corrosive ingredients
- *Toxicity Ranking:* Low
- *Exposure Ranking:* Medium
- *Hazard Ranking:* Medium-Low

A.7. ESOH ANALYSIS OF KIMETSAN AST D45-AMS

A.7.1. Environmental Issues

- *Air Emissions per CAA:*
  - Tuluol (Toluene)
  - VOC content: 150 g/L
- *Solid/Hazardous Waste Generation per RCRA:*
  - Tuluol (Toluene)
- *EPCRA Reporting Requirements*:
  - Tuluol (Toluene)
- *CERCLA Hazardous Substances*:
  - Tuluol (Toluene)

A.7.2. Health & Safety Issues

Although the product says that it is isocyanate-free, a test of a bulk sample of components A and B for isocyanates is recommended.

- *Acute Effects (short term)*
  - Working in badly ventilated areas may cause dizziness, indisposition and headache
- *Chronic Effects (long term)*
  - None listed
- *Inhalation*
  - None listed
- *Skin contact*
  - None listed
- *Eye contact*
  - None listed
- *Special Precautions*
  - Respiratory: Air-Purifying Respiratory (APR)/Powered Air-Purifying Respirator (PAPR) for organic vapor/spray mist (SAR if free isocyanates are present); Supplied-Air Respirator (SAR) for confined spaces
  - Skin: Tyvek or other disposable coveralls; gloves/barrier cream recommended for exposed skin; safety shower or washing facility required
  - Eye: Full face respirator for spray application; splash goggles with faceshield when mixing components; eyewash required
- *Toxicity Ranking:* Medium
- *Exposure Ranking:* High
- *Hazard Ranking:* Medium-High

A.8. ESOH ANALYSIS OF SHERWIN WILLIAMS FAST CLAD HB

A.8.1. Environmental Issues

- *Air Emissions per CAA:*
  - Glycol ethers
  - VOC content: 164 g/L
- *Solid/Hazardous Waste Generation per RCRA:*
  - NONE
- *EPCRA Reporting Requirements*:
  - Glycol ethers
- *CERCLA Hazardous Substances*:
  - NONE

A.8.2. Health & Safety Issues

- *Acute Effects (short term)*
  - In confined area, vapors in high concentration may cause headache, nausea or dizziness
  - Redness and itching or burning sensation may indicate eye or excessive skin exposure
- *Chronic Effects (long term)*
  - None listed
- *Inhalation*
  - Irritation of the upper respiratory system
- *Skin contact*
  - Prolonged or repeated exposure may cause irritation
- *Eye contact*
  - Causes irritation
- *Special Precautions*
  - Respiratory: Air-Purifying Respiratory (APR)/Powered Air-Purifying Respirator (PAPR) for organic vapor/spray mist; Supplied-Air Respirator (SAR) for confined spaces
  - Skin: Tyvek or other disposable coveralls
  - Eye: Full face respirator for spray application; splash goggles with faceshield when mixing components; eyewash required
- *Toxicity Ranking:* Low
- *Exposure Ranking:* Low
- *Hazard Ranking:* Low

A.9. ESOH ANALYSIS OF SHERWIN WILLIAMS POLYSILOXANE XLE

A.9.1. Environmental Issues

- *Air Emissions per CAA:*
    - Ethyl benzene (Part B)
    - Xylene (Part B)
    - VOC content: 101 g/L
- *Solid/Hazardous Waste Generation per RCRA:*
    - Ethyl benzene (Part B)
    - Xylene (Part B)
- *EPCRA Reporting Requirements*:
    - Ethyl benzene (Part B)
    - Xylene (Part B)
- *CERCLA Hazardous Substances*:
    - Ethyl benzene (Part B)
    - Xylene (Part B)

A.9.2. Health & Safety Issues

- *Acute Effects (short term)*
    - Headache, dizziness, nausea, and loss of coordination are indications of excessive exposure to vapors or spray mists (Parts A and B)
    - Redness and itching or burning sensation may indicate eye or excessive skin exposure (Parts A and B)
- *Chronic Effects (long term)*
    - Reports have associated repeated and prolonged overexposure to solvents with permanent brain and nervous system damage (Part A)
- *Inhalation*
    - Irritation of the upper respiratory system (Part A)
    - Causes burns of the upper respiratory system (Part B)
    - May cause nervous system depression. Extreme overexposure may result in unconsciousness and possibly death (Part B)
- *Skin contact*
    - Prolonged or repeated exposure may cause irritation (Part A)
    - May cause allergic skin reaction in susceptible persons or skin sensitization (Part A)
    - Causes burns (Part B)
- *Eye contact*
    - Causes irritation (Part A)
    - Causes burns (Part B)
- *Special Precautions*
    - Respiratory: Air-Purifying Respiratory (APR)/Powered Air-Purifying Respirator (PAPR) for organic vapor/spray mist; Supplied-Air Respirator (SAR) for confined spaces

  - Skin: Tyvek or other disposable coveralls; gloves/barrier cream recommended for exposed skin; safety shower or washing facility required
  - Eye: Full face respirator for spray application; splash goggles with faceshield when mixing components; eyewash required
  - Skin sensitizer in Part A (epoxy) requires PPE when handling/mixing
  - Corrosive warning for Part B (polyamine)
- *Toxicity Ranking:* Medium
- *Exposure Ranking:* Medium
- *Hazard Ranking:* Medium

A.10. ESOH ANALYSIS OF SHERWIN WILLIAMS SHER-CRYL HPA

A.10.1. Environmental Issues

- *Air Emissions per CAA:*
  - Glycol ethers
  - VOC content: 200 g/L
- *Solid/Hazardous Waste Generation per RCRA:*
  - Glycol ethers
- *EPCRA Reporting Requirements*:
  - Glycol ethers
- *CERCLA Hazardous Substances*:
  - Glycol ethers

A.10.2. Health & Safety Issues

- *Acute Effects (short term)*
  - In a confined area, vapors in high concentration may cause headache, nausea or dizziness
  - Redness and itching or burning sensation may indicate eye or excessive skin exposure
- *Chronic Effects (long term)*
  - None listed
- *Inhalation*
  - Irritation of the upper respiratory system
- *Skin contact*
  - Prolonged or repeated exposure may cause irritation
- *Eye contact*
  - Causes irritation
- *Special Precautions*
  - Respiratory: Air-Purifying Respiratory (APR)/Powered Air-Purifying Respirator (PAPR) for organic vapor/spray mist; Supplied-Air Respirator (SAR) for confined spaces
  - Skin: Tyvek or other disposable coveralls
  - Eye: Full face respirator for spray application; splash goggles with faceshield when mixing components; eyewash required
- *Toxicity Ranking:* Low
- *Exposure Ranking:* Low
- *Hazard Ranking:* Low

APPENDIX B
(Separate Document)

Material Safety Data Sheets
For
Viable Alternatives Selected for Testing
Under this Project

APPENDIX C
(Separate Document)

Material Safety Data Sheets For Alternatives Removed from Further Consideration Under this Project