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LTPC Phase II Laboratory Test Plan and Procedures (Rev D)

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List of Acronyms

AGE	Aircraft Ground Equipment
ASTM	American Standard Test Method
COTS	Commercial-Off-the-Shelf
DFT	Dry Film Thickness
DoD	Department of Defense
ETP	Experimental Test Plan
F	Fahrenheit
FOD	Foreign Object Damage
HALS	Hindered Amine Light Stabilizers
HAP	Hazardous Air Pollutants
LTPC	Low Temperature Powder Coating
MIC	Microbial Influenced Corrosion
PACAF	Pacific Air Forces
RH	Relative Humidity
SOW	Statement of Work
TM	Technical Manual
UDRI	University of Dayton Research Institute
UV	Ultra Violet
VCI	Vapor Corrosion Inhibitor
VOC	Volatile Organic Compound

CDRL A004 Revision Details

Revision	Revision Details
A	Addressed the clarification questions referenced in Section 6 of the Report
B	Modified the LTPC curing cycles to a max curing temperature of 275ºF on Al 2024 panels substrates and 295ºF for Al 6061 and steel alloy substrates.
C	Revised curing temperature for Al 2024 panel substrates to 295°F for 30 minutes in accordance with Jason McDuffie's e-mail dated 03/09/2018
D	Revised Table 2. MIC Inhibitor # 3 in stackup P5 changed from ***Triazine Compounds*** to ***Silver Ion*** to address REACH concerns.

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1.0 Background

Traditional military coating systems formulated with Volatile Organic Compounds (VOCs) and Hazardous Air Pollutants (HAPs) burden the Air Force and other Department of Defense (DoD) agencies with environmental compliance, permitting, tracking, storage, operations, disposal, and reporting requirements. In addition, the handling and disposal of toxic hazardous wastes associated with the removal and reapplication of the hexavalent chromium containing primers in traditional coating systems is costly, time consuming, and represents a risk to health, safety, and the environment.

Powder coatings represent a mature technology that eliminates the hazardous waste streams (e.g., air emissions, contaminated booth filters, unused admixed paints and cleaning solvents) associated with conventional wet painting operations. Advantages over conventional wet painting include greater coating durability, elimination of VOCs and HAPs, improved transfer efficiency, and the elimination of drips, runs, and blistering defects. Additionally, powder coating also reduces employee exposure to HAPs and liabilities associated with wet painting.

This project is Phase II of a comprehensive evaluation of three commercially available Low Temperature Powder Coatings (LTPCs) completed by Battelle in 2014. The evaluation ranked Hentzen's Crosslink LTPC as the best with recommendations to improve its resistance to Ultraviolet (UV) light and microbiologically influenced Corrosion (MIC). The scope of this Phase II is to modify/reformulate the Commercial-Off-The-Shelf (COTS) Hentzen (Crosslink) (LTPC) No. 6191-61003 to support Aerospace Ground Equipment (AGE) at Pacific Air Force (PACAF) locations.

This Revision A of the Laboratory Test Plan and Procedures developed for Phase II takes into consideration and addresses the Air Force comments received in response to the earlier version submitted on 31 January 2018. Please refer to Table 10 of this document for Air Force Comments and Battelle's response.

2.0 Scope

The intent of this laboratory test plan / Experimental Test Plan (ETP) is to provide comprehensive evaluation procedures to evaluate performance of the LTPC formulations for UV and MIC resistance. At end of this task, three best performing LTPC formulations will be down-selected for beachfront testing. **Note:** The project's Performance Work Statement (PWS) requires that the Laboratory Test Plan and Procedures developed for this Phase II follow the ETP developed during the Phase I of the project. While this ETP is focused on meeting the objectives of this Phase II, it follows the PWS requirements, and limits the deviations from the phase I ETP to critical factors. For example, the number of test specimen are increased from three (3) to five (5) for each test and from single (1) to triplicates (3).

Following are the key objectives of this task:

1) An evaluation of the five reformulated LTPCs with UV and MIC resistance additives for AGE application against the current wet coating stack-up identified in Technical Order (TO) 35-1-3 and the Control LTPC.
    1. Control LTPC - COTS LTPC (No UV or MIC additives)
    2. COTS LTPC + Hindered Amine Light Stabilizers (HALS) + cocktail of MIC 1,2, & 3
    3. COTS LTPC + MIC Inhibitor #1 + HALS
    4. COTS LTPC + MIC Inhibitor #2 + HALS
    5. COTS LTPC + MIC Inhibitor #3 + HALS
    6. COTS LTPC (Anti-microbial resin modification to reduce MIC)

7. Control – MIL-PRF-23377 TY I Class C2 strontium chromate-based primer with MIL-PRF-85285E TY IV CL H topcoat

2) Panel testing at Battelle and subcontracted testing laboratories that includes salt fog, adhesion, weatherability, and chip resistance testing.

3) Accelerated MIC testing to quantitatively assess biocidal effectiveness using ASTM E2180-07 to confirm the presence of antimicrobial activity on COTS LTPC panels.

3.0 Technical Approach

This assessment will be completed by conducting the following test panel processing, testing, and data analysis activities.

3.1 Application of Coating System Stack-ups to Test Panels

The four representative substrates selected for this study include a combination of two steel alloys (4130 and 1010) and two aluminum alloys (2024-T3 and 6061-T6). The selection of these alloys was based on conversations with major stakeholders, previous LTPC projects, and a review of available technical literature. Panels will be sheared to a size of 4.0" x 6.0" and have a nominal thickness of 0.032". All panels will receive a unique identification code prior to pre-treatment. Once a unique identifier is placed on the panels, the panels will be packaged in vapor corrosion inhibitor (VCI) paper and stored until a processing schedule is finalized. All handling of the panels will include clean latex gloves to eliminate contamination that may impact the quality of the respective treatments. The legends that will be used to identify the substrate and coating stack-up of each test panel are presented in Table 1.

Table 1 Legends for Substrate and Pre-treatment

Substrate ID	Substrate Material	Surface Treatment
AL1	Aluminum 2024-T3	MIL-A-8625 TY II anodize [1]
AL2	Aluminum 6061-T6	MIL-A-8625 TY II anodize [1]
ST1	Carbon Steel 4130	TT-C-490F zinc phosphate [2]
ST2	Carbon Steel 1010	TT-C-490F zinc phosphate [2]
[1] Surface treatment in accordance with TO 35-1-3 table 3.1 section 2 pretreatment		
[2] Surface treatment in accordance with TO 35-1-3 table 3.1 section 1 pretreatment		

The legends that will be used for the coatings stack-ups are presented in Table 2 below. Stack-up P1 and W1 are Control stack-up for powder and wet coatings respectively while stack-ups P2 - P6 are the five (5) candidate reformulated coatings to be evaluated on this task.

Table 2 Legends for Coating Stack-up

Stack-up	Primer	Topcoat
P1	Hentzen (P-70172AEE) Epoxy Powder Primer	LTPC control (No UV or MIC additives)
P2		LTPC + HALS + cocktail of MIC 1,2, & 3
P3		LTPC + MIC Inhibitor #1 (Quaternary Ammonium Compound) + HALS
P4		LTPC + MIC Inhibitor #2 (Organosilicon Compounds) + HALS
P5		LTPC + MIC Inhibitor #3 (Silver Ion) + HALS
P6		LTPC (Anti-microbial resin modification to reduce MIC)
W1	MIL-PRF-23377 TY 1 CL C2 [1]	MIL-PRF-85285E TY IV CL H
[1] Prime in accordance with TO 35-1-3 table 3.1 section 3 primer		

3.1.1 Surface Treatments

A non-chromate chemical conversion coating that conforms to the MIL-A-8625 Type II specification will be the surface treatment applied to the non-ferrous substrates. A zinc-phosphate surface treatment conforming to the specification TT-C-490F Type I, Class A will be applied to the ferrous substrates. Battelle will subcontract the pretreatments to a local subcontractor.

3.1.2 Primers

Hentzen's epoxy-based powder primer (P-70172 AEE) will be used on ferrous and aluminum panels for application of the LTPC formulations. The target thickness for this primer will be 2 to 3 mils and per the manufacturer's specifications, it will be cured at 295°F for 30 minutes for both the steel and aluminum test panels.

All anodized aluminum panels and ferrous panels treated with the zinc phosphate TT-C-490F that are slated to be coated with the control wet coating MIL-PRF-85285 will be processed with a primer that is approved under the MIL-PRF-23377J, Type I, Class C2 specification. The target DFT for the primer layer will be 0.6 - 0.9 mils. Battelle will use a cross coat application method to achieve this film build.

3.1.3 Topcoats

As discussed in Table 2, Hentzen will apply the LTPC coating stackup on six (6) different sets of pretreated test panels supplied by Battelle as follows;

- The five different reformulated versions of LTPC developed under this Phase II will be applied to five (5) sets of pretreated test panels.
- The control or baseline Hentzen COTS LTPC No. 6191-61003 that was evaluated and ranked as the best performing during Phase 1 will be applied to the remaining set of test panels.

The dry film thickness (DFT) of the LTPC formulation topcoats will be .002" to .003" for ferrous and nonferrous panels. The steel and aluminum panels will be cured at 295 °F for 30 minutes . Battelle will work closely with Hentzen during the application of the powder coatings to test panels.

The laboratory testing wet control non-ferrous and ferrous panels will be coated with Hentzen MIL-PRF-85285E Type IV, Class H topcoat. This topcoat is currently being applied to Air Force AGE because of its extended weatherability. As is specified in T.O 35-1-3 Table 3-1, the target DFT for this topcoat is 1.6 to 2.4 mils. A cross-coat application method will be used to achieve this film build. Reference panels will be sprayed at the same time the coating is applied to the test panels to measure the wet film thickness and resultant DFT measurement. The coated panels will be cured in a controlled constant temperature-humidity environment (70 °F and 50% RH) for a minimum of 4 days prior to the beginning of any testing.

3.2 Laboratory Panel Testing

The laboratory testing of the test panels will primarily focus on evaluating the coatings performance for improved resistance to the UV light and MIC. A series of standard coatings performance assessment tests are included in the test plan. Multiple tests are planned for evaluation of LTPC formulation for improved resistance to MIC along with simultaneous validation checks for the effect and functionality of the inhibitors and additives. Majority of the tests will be performed at Battelle. Test for chipping resistance and weatherability will be performed at the University of Dayton Research Institute (UDRI).

3.2.1 Corrosion Test

The neutral salt fog testing of 4.0" x 6.0" x 0.032" coated panels will be conducted at Battelle in accordance with the practice outlined in ASTM B117-03: Standard Practice for Operating Salt Spray (Fog) Apparatus. Five replicate panels will be exposed for each substrate and unique coating stack-up. Three of the panels for each coating stack-up will be single-line scribed to evaluate the coating performance when the substrate is exposed (due to damage or some other compromising agent). The remaining panels in each set will be tested intact or with scribing. All test panels will be positioned on plastic test racks in a Singleton salt fog chamber that is maintained at 95 °F. All panels will be inclined at an angle of 15 degrees from vertical throughout the entire 2,000-hour test exposure period. The pH of the test solution that will be continually misted throughout the chamber will be between 6.5 and 7.2. The matrix for the panels to be used in the salt fog testing is provided in Table 3.

Table 3 Salt Fog Testing Matrix

Substrate	Surface Treatment	Primer	Topcoat	Total # Panels
AL1, AL2	MIL-A-8625 TY II	Hentzen (P-70172AEE) Epoxy Primer	LTPC (No UV or MIC additives)	10
ST1, ST2	TT-C-490F		LTPC (No UV or MIC additives)	10
AL1, AL2	MIL-A-8625 TY II		LTPC + HALS + cocktail of MIC 1,2, & 3	10
ST1, ST2	TT-C-490F		LTPC + HALS + cocktail of MIC 1,2, & 3	10
AL1, AL2	MIL-A-8625 TY II		LTPC + MIC Inhibitor #1 + HALS	10
ST1, ST2	TT-C-490F		LTPC + MIC Inhibitor #1 + HALS	10
AL1, AL2	MIL-A-8625 TY II		LTPC + MIC Inhibitor #2 + HALS	10
ST1, ST2	TT-C-490F		LTPC + MIC Inhibitor #2 + HALS	10
AL1, AL2	MIL-A-8625 TY II		LTPC + MIC Inhibitor #3 + HALS	10
ST1, ST2	TT-C-490F		LTPC + MIC Inhibitor #3 + HALS	10
AL1, AL2	MIL-A-8625 TY II		LTPC (Anti-microbial resin modification to reduce MIC)	10
ST1, ST2	TT-C-490F		LTPC (Anti-microbial resin modification to reduce MIC)	10
AL1, AL2	MIL-A-8625 TY II	MIL-PRF-23377 TY 1 CL C2	MIL-PRF-85285E TY IV CL H	10
ST1, ST2	TT-C-490F		MIL-PRF-85285E TY IV CL H	10
			Total:	**140**

3.2.1.1 Corrosion Test Evaluation of Panels

Panels will be visually inspected for scribe corrosion and coating edge creep damage as well as coating system blistering after 24-hours, 500-hours, 1,000-hours, 1,500-hours and 2,000-hours in accordance with ASTM D1654-08 Standard Test Method for Evaluation of Painted or Coated Specimens Subjected to Corrosive Environments. All inspections will include a tabulated summary of observed visible damage, and photographs will be used to document representative damage trends. Collectively, the results from the accelerated laboratory salt fog testing will be used for generating a comparison of the coating performance results between LTPC formulations and the control wet coating.

3.2.2 Coating Adhesion Test

The adhesion testing of 4.0” x 6.0” x 0.032” coated panels will be conducted by a Battelle technician experienced with the test outlined in ASTM D3359-02 Test Method B: Cross-cut Tape Test. The number and spacing of cuts will be determined based on the thickness of the total coating system stack-up. Three replicate cross-cut tape tests will be performed per panel. All tests will be performed by the same technician to eliminate any variance in results. Each panel will be photographed after the test. The photographs and results will be recorded, reviewed and used in the coating down-selection process. Table 4 presents the panel matrix for the adhesion tests.

Table 4 Adhesion Testing Matrix

Substrate	Surface Treatment	Primer	Topcoat	Total # Panels
AL1, AL2	MIL-A-8625 TY II	Hentzen (P-70172AEE) Epoxy Primer	LTPC (No UV or MIC additives)	10
ST1, ST2	TT-C-490F		LTPC (No UV or MIC additives)	10
AL1, AL2	MIL-A-8625 TY II		LTPC + HALS + cocktail of MIC 1,2, & 3	10

Substrate	Surface Treatment	Primer	Topcoat	Total # Panels
ST1, ST2	TT-C-490F		LTPC + HALS + cocktail of MIC 1,2, & 3	10
AL1, AL2	MIL-A-8625 TY II		LTPC + MIC Inhibitor #1 + HALS	10
ST1, ST2	TT-C-490F		LTPC + MIC Inhibitor #1 + HALS	10
AL1, AL2	MIL-A-8625 TY II		LTPC + MIC Inhibitor #2 + HALS	10
ST1, ST2	TT-C-490F		LTPC + MIC Inhibitor #2 + HALS	10
AL1, AL2	MIL-A-8625 TY II		LTPC + MIC Inhibitor #3 + HALS	10
ST1, ST2	TT-C-490F		LTPC + MIC Inhibitor #3 + HALS	10
AL1, AL2	MIL-A-8625 TY II		LTPC (Anti-microbial resin modification to reduce MIC)	10
ST1, ST2	TT-C-490F		LTPC (Anti-microbial resin modification to reduce MIC)	10
AL1, AL2	MIL-A-8625 TY II	MIL-PRF-23377 TY 1 CL C2	MIL-PRF-85285E TY IV CL H	10
ST1, ST2	TT-C-490F		MIL-PRF-85285E TY IV CL H	10
			Total:	**140**

3.2.3 Xenon-Arc Weatherability

Battelle will utilize the resources of UDRI to conduct the test outlined in ASTM D6695-16 cycle 1 Xenon-Arc Exposure of Paint and Related Coatings. As noted in Table 5, Five (5) coated panels will be tested for each type of substrate. All panels will undergo the procedures outlined in ASTM G 155, a procedure that calls for a spectrum very close to natural sunlight. The test protocol also uses periodic water sprays to simulate the synergistic effects of sun and rain. Specifically, the testing will include a spectral irradiance of 0.35 watts/meter^2, a black panel temperature of 63 °C (± 2.5 °C), and an exposure cycle of 102 minutes of light exposure followed by light and water spray for 18 minutes, repeating for 500 cycles or 1000 hours.

Table 5 Xenon-Arc Testing Matrix

Substrate	Surface Treatment	Primer	Topcoat	Total # Panels
AL1, AL2	MIL-A-8625 TY II	Hentzen (P-70172AEE) Epoxy Primer	LTPC (No UV or MIC additives)	10
ST1, ST2	TT-C-490F		LTPC (No UV or MIC additives)	10
AL1, AL2	MIL-A-8625 TY II		LTPC + HALS + cocktail of MIC 1,2, & 3	10
ST1, ST2	TT-C-490F		LTPC + HALS + cocktail of MIC 1,2, & 3	10
AL1, AL2	MIL-A-8625 TY II		LTPC + MIC Inhibitor #1 + HALS	10
ST1, ST2	TT-C-490F		LTPC + MIC Inhibitor #1 + HALS	10
AL1, AL2	MIL-A-8625 TY II		LTPC + MIC Inhibitor #2 + HALS	10
ST1, ST2	TT-C-490F		LTPC + MIC Inhibitor #2 + HALS	10
AL1, AL2	MIL-A-8625 TY II		LTPC + MIC Inhibitor #3 + HALS	10
ST1, ST2	TT-C-490F		LTPC + MIC Inhibitor #3 + HALS	10
AL1, AL2	MIL-A-8625 TY II		LTPC (Anti-microbial resin modification to reduce MIC)	10
ST1, ST2	TT-C-490F		LTPC (Anti-microbial resin modification to reduce MIC)	10
AL1, AL2	MIL-A-8625 TY II	MIL-PRF-23377 TY 1 CL C2	MIL-PRF-85285E TY IV CL H	10
ST1, ST2	TT-C-490F		MIL-PRF-85285E TY IV CL H	10
			Total:	**140**

3.2.3.1 Xenon-Arc Evaluation of Panels

Panels subjected to Xenon-Arc exposure will have the L*, a*, b* coordinates measured with a Datacolor International Spectraflash SF 600 spectrophotometer in accordance with ASTM D2244. The ΔL*, Δa*, Δb* and ΔE will be calculated post 1000 hours of exposure. The 60° angle of incidence gloss reading will be taken with a BYK Gardner micro-TRI-gloss meter in accordance with ASTM D523 on each panel before exposure and post 1000 hours of exposure to show the effect of UV on the gloss reading of each formulation. Photographs will be taken of each panel before and after exposure.

3.2.4 Gravelometer

ASTM D3170 Chipping Resistance of Coatings testing will be conducted at the UDRI. As shown in Table 6, five (5) 4.0” x 6.0” x 0.032” coated panel representing each type of substrate and coating system stack-up will be tested.

The Gravelometer is designed to evaluate the resistance of surface coating systems to chipping caused by the impacts of gravel or foreign object damage (FOD). The primary usage of this test is to simulate the effects of the impact of gravel or other debris on moving parts. After the gravel impact, tape will be applied to the impacted area to remove any loose coating chips and the degree of the chipping will be determined. As required, any damaged areas will be documented with photographs.

Table 6 Gravelometer Testing Matrix

Substrate	Surface Treatment	Primer	Topcoat	Total # Panels
AL1, AL2	MIL-A-8625 TY II	Hentzen (P-70172AEE) Epoxy Primer	LTPC (No UV or MIC additives)	10
ST1, ST2	TT-C-490F		LTPC (No UV or MIC additives)	10
AL1, AL2	MIL-A-8625 TY II		LTPC + HALS + cocktail of MIC 1,2, & 3	10
ST1, ST2	TT-C-490F		LTPC + HALS + cocktail of MIC 1,2, & 3	10
AL1, AL2	MIL-A-8625 TY II		LTPC + MIC Inhibitor #1 + HALS	10
ST1, ST2	TT-C-490F		LTPC + MIC Inhibitor #1 + HALS	10
AL1, AL2	MIL-A-8625 TY II		LTPC + MIC Inhibitor #2 + HALS	10
ST1, ST2	TT-C-490F		LTPC + MIC Inhibitor #2 + HALS	10
AL1, AL2	MIL-A-8625 TY II		LTPC + MIC Inhibitor #3 + HALS	10
ST1, ST2	TT-C-490F		LTPC + MIC Inhibitor #3 + HALS	10
AL1, AL2	MIL-A-8625 TY II		LTPC (Anti-microbial resin modification to reduce MIC)	10
ST1, ST2	TT-C-490F		LTPC (Anti-microbial resin modification to reduce MIC)	10
AL1, AL2	MIL-A-8625 TY II	MIL-PRF-23377 TY 1 CL C2	MIL-PRF-85285E TY IV CL H	10
ST1, ST2	TT-C-490F		MIL-PRF-85285E TY IV CL H	10
			Total:	**140**

3.2.5 Mandrel Bend Test

ASTM D522-17 test method B will be utilized as the primary test for rating the reformulated LTPCs for resistance to cracking. The reformulated LTPCs will be applied to 3” x 6” x 0.032” aluminum 2024 panels. The panels will be bent over varying diameter mandrels 180° until cracking of the coating is noticed with the unaided eye. The mandrels include diameters of 25 mm [1 in], 19 mm [3⁄4 in.], 12.7 mm [1⁄2 in.], 9.5 mm [3⁄8 in.], 6.4 mm [1⁄4 in.], and 3.2 mm [1⁄8 in.]. The testing will begin with the 1” diameter mandrel and continue onto increasingly smaller mandrels until cracking is observed. The last mandrel used that did not cause visible cracking will be considered the formulations rating. The test matrix for the mandrel bend test is presented in Table 7.

Table 7 Mandrel Bend Testing Matrix

Substrate	Surface Treatment	Primer	Topcoat	Total # Panels
AL1	MIL-A-8625 TY II	Hentzen (P-70172AEE) Epoxy Primer	LTPC (No UV or MIC additives)	5
AL1	MIL-A-8625 TY II		LTPC + HALS + cocktail of MIC 1,2, & 3	5
AL1	MIL-A-8625 TY II		LTPC + MIC Inhibitor #1 + HALS	5
AL1	MIL-A-8625 TY II		LTPC + MIC Inhibitor #2 + HALS	5
AL1	MIL-A-8625 TY II		LTPC + MIC Inhibitor #3 + HALS	5
AL1	MIL-A-8625 TY II		LTPC (Anti-microbial resin modification to reduce MIC)	5
AL1	MIL-A-8625 TY II	MIL-PRF-23377 TY 1 CL C2	MIL-PRF-85285E TY IV CL H	5
			Total:	**35**

3.2.6 MIC Testing

ASTM E2180-07 will be utilized as the primary test for microbial growth, with MIL-STD-810G Method 508.7 as a backup method. While most of the ASTM protocols state to run the tests for approximately 4 weeks, it is generally recommended to let the tests run for up to 3 months (~90 days) for a greater degree of certainty (less risk) in determining the existence or effect of microbial growth. Thus, to preserve timelines, duplicate sets of panels will be tested at both 30 days and 84 days. Growth will also be checked at approximately 7-day time points to observe bacterial growth, as bacteria grows faster than fungi. ASTM D5590-00 ("Accelerated Four-Week Agar Plate Assay") will not be used as it is very similar to ASTM E2180-07. The applied coatings on the test panels can be exposed to accelerated weathering and then tested, however, there is no mechanism to accelerate microbial growth itself cannot be accelerated; only, which does not fit into the timeline of this program. Additionally, ASTM-D-3274 is intended for field use for the macro rating of surface disfigurement only. This test is not meant to be a laboratory test and so will not be utilized here.

The method described in ASTM E2180-07 is designed to evaluate the antimicrobial effectiveness of agents incorporated or bound to hydrophobic or polymeric surfaces. An agar slurry of a consortium (mixture) of bacteria and fungi will be used as a “pseudo biofilm” to confirm the presence of antimicrobial activity, which will allow for quantitative results of differences in antimicrobial activity between untreated plastics or polymers and those with bound or incorporated low water-soluble antimicrobial agents. Comparisons between the numbers of surviving microorganisms on preservative treated and control hydrophobic surfaces will also be made. A composite sample with consortia from all the three sites (Table 8) will be tested. Please see Table 9 for the test matrix to be tested for the Microbial consortium.

Table 8. List of Microbial Consortia from Across All Sites

Prevalent MIC-causing Bacteria across the three PACAF Locations	Prevalent MIC-causing Fungi across three PACAF Locations
Sphingomonas	*Exophiala*
Acidovorax / Variovorax	*Dothideomycetes*
Pseudomonas / Brevundimonas	*Aureobasidium*
Massilia	*Toxicocladosporium / Cladosporium*
Methylobacterium	*Aspergillus*
	Penicillium
	Nigrospora

Table 9 MIC Test Matrix

Substrate	Surface Treatment	Primer	Topcoat	Total # Panels
AL1, AL2	MIL-A-8625 TY II	Hentzen (P-70172AEE) Epoxy Primer	LTPC (No UV or MIC additives)	6
ST1, ST2	TT-C-490F		LTPC (No UV or MIC additives)	6
AL1, AL2	MIL-A-8625 TY II		LTPC + HALS + cocktail of MIC 1,2, & 3	6
ST1, ST2	TT-C-490F		LTPC + HALS + cocktail of MIC 1,2, & 3	6
AL1, AL2	MIL-A-8625 TY II		LTPC + MIC Inhibitor #1 + HALS	6
ST1, ST2	TT-C-490F		LTPC + MIC Inhibitor #1 + HALS	6
AL1, AL2	MIL-A-8625 TY II		LTPC + MIC Inhibitor #2 + HALS	6
ST1, ST2	TT-C-490F		LTPC + MIC Inhibitor #2 + HALS	6
AL1, AL2	MIL-A-8625 TY II		LTPC + MIC Inhibitor #3 + HALS	6
ST1, ST2	TT-C-490F		LTPC + MIC Inhibitor #3 + HALS	6
AL1, AL2	MIL-A-8625 TY II		LTPC (Anti-microbial resin modification to reduce MIC)	6
ST1, ST2	TT-C-490F		LTPC (Anti-microbial resin modification to reduce MIC)	6
AL1, AL2	MIL-A-8625 TY II	MIL-PRF-23377 TY 1 CL C2	MIL-PRF-85285E TY IV CL H	6
ST1, ST2	TT-C-490F		MIL-PRF-85285E TY IV CL H	6
			Total:	**84**

3.2.6.1 Analysis of MIC Tests

Results of MIC tests will be analyzed for microbial and chemical effects as discussed below.

3.2.6.1.1 Microbial

Bacterial cultures will be inoculated into agar slurries and will then be transferred onto test and control samples, and incubated at the appropriate temperatures. Serial dilutions of the agar slurry will be spread plated immediately at “0” h to determine the cfu/mL recoverable at the time of inoculation. After incubation, samples will be sonicated, vortexed, and serial dilutions will be performed to determine the number of colonies from each sample.

3.2.6.1.2 Chemical Analysis

After testing is complete, any samples with heavy microbial growth will be further analyzed by Scanning Electron Microscopy coupled with Electron Dissipative X-Ray Spectroscopy (SEM-EDAX). This will allow a more thorough analysis of the samples, including looking at pitting, and any corrosion byproducts left behind bacteria and fungi within the pitting. Identification of corrosion byproducts by SEM-EDAX will help to provide a better downstream formulation plan for the LTPC and MIC inhibitors.

4.0 Down-Selection and Recommendation of Modified COTS LTPC

Based on the results and analysis of the laboratory testing, Battelle in cooperation with Hentzen will down select the three best performing modified COTS LTPC formulations. These three formulations will be used for beachfront exposure task as well as the USAF field review. The field review will consist of Battelle purchasing three maintenance stands (B-1, B-4, etc.) and/or a towbar (C-17, KC-135, MD-1, etc.) of a similar size and type structure utilized with AGE equipment. Battelle will employ a subcontractor to apply the three down-selected LTPC formulations to the purchased AGE. Battelle will provide this vendor with the three down selected modified LTPC powder formulations which they will apply on new equipment. Battelle will then have the equipment shipped to Anderson AFB for the USAF field evaluation.

5.0 Report

Performance data from results of the coatings systems compiled throughout the laboratory testing will be analyzed and documented. Three best performing modified COTS LTPC formulations will be downselected for the beachfront testing. The Laboratory Test results will be presented in CDRL A005, Test/Inspection Report.

6.0 Air Force Comments/Clarifications with Response

Battelle received review comments and clarification questions in response to the Laboratory Test Plan and Procedures / ETP submitted on Phase II. These comments and Battelle's responses are summarized below in Table 10.

Table 10. Air Force Comments to Phase II ETP and Battelle's Response.

ETP Section	Air Force Comment	Battelle Response
2.0	Make sure Type IV of 85285 is used as this has superior UV protection over Type I and is now more commonly used. Also, specify Class H of this topcoat.	Noted. Hentzen MIL-PRF-85285 TY IV CL H topcoat, will be used for wet coating control panels in the laboratory testing and is shown in the relevant Test Matrix Tables.
2.0	Any stripability testing? The maintainers want something that can be removed for NDI and repaint purposes.	No stripability test is planned for this phase. We will make recommendations for paint removal under PWS 4.3.2 Technical Order 35-1-3 review and recommendations.
3.1 Table 1	Type II or Type IIB? Type II can cause a fairly deep chemical etch. I don't think Type II would typically be used on a substrate as thin as 0.032", especially in the A/C realm.	Type II was selected based on AGE as the application and not A/C. However, IIB could be applied and is in discussion with the surface treatment vendor.
3.1 Table 1	Which cleaning method will be used IAW TT-C-490 prior to application of the chem conversion coating?	The test panels will be cleaned in accordance with TT-C-490 method I mechanical or abrasive cleaning.
3.1.2	I'm not sure, but this temp may not be suitable for the aluminum panels. Might want to take another look into when their heat treatments start to be impacted prior to starting the study.	The powder coating cure conditions (temp and time) in the ETP are recommended by Hentzen to get optimum performance from the reformulated COTS powder coating No. 6191-61003. Hentzen has recommended a 295°F bake for 30 minutes cycle each for the powder primer and topcoat. Battelle's subject matter expert on structural properties of metallic materials provided the following assessment in response to the concern expressed in the review comments; From Figures 3.2.4.1.1(e) and (f) of Metallic Materials Properties Development and Standardization (MMPDS)-12 Handbook, when exposed at about 300°F over 30 to 60 minutes, Al 2024-T3 could be expected to produce about a 2% loss in subsequent room temperature tensile strength and 7% loss in subsequent room temperature yield strength.

ETP Section	Air Force Comment	Battelle Response
		Figures 3.6.2.2.1(c) and (d) of MMPDS-12 show that for the same exposure of Al6061-T6 could be expected to produce a minimal effect on subsequent room temperature tensile and yield strength. Through subsequent revisions, on this Revision C, the final version for Test Plan and Procedures, the decision was to cure both, the ferrous and non-ferrous test panels at 295 ^{o}F for 30 minutes.
3.1.2	Chrome primers aren't the best protection against ferrous substrates and I believe Stephen's calls for a 26915 Zn-rich primer, which would have superior performance. Unfortunately, there are no vendors on the QPL. Type I, Form A, Class S of MIL-PRF-32550 is a suitable substitute while 26915 primers are being qualified.	We are aware that the preferred stack-up for ferrous substrates would include a zinc-rich primer. We chose the proposed stack-up in the ETP based on the PWS section 4.4 which states that control coatings to assess biocidal effectiveness and performance shall be hexavalent chromium based and approved by AFLCMC/WNZE. Based on that stated requirement we proposed using the stack-up shown in TO 35-1-3 Table 3.1 section 3. Which allows for a MIL-PRF-23377 class C primer on bare ferrous alloys.
3.1.2	You may want to add an additional coating stack-up that consists of Class N, which is the non-chromated form of this primer. To my knowledge, almost no assets are procured out of SE&V with Class C2 (see Stephen's template). Definitely leave Class C2 in the test plan, however, as this is what is almost always used in touch-up and repaint operations once an asset hits the base.	Based on the RFP and the PWS, we only accounted for one wet coating control stack-up. We did not price for additional wet control stack-ups. The additional coating stack-up could be included but that will require change order and schedule change.
3.1.3	Type II is listed as a support equipment coating; however, I've never seen this product in the field. I would suggest adding Type IV as this is most representative of what's used.	MIL-PRF-85285 TY IV CL H will be used.
3.2	A panel will only be used for one test, correct? In other words, a panel won't be UV tested, then subjected to corrosion testing, etc.?	Correct, one panel will be used for one test only.
3.2.1	Salt fog testing tests for corrosion inhibition of a primer, but understand going into this that it poorly replicates performance in the field. For example, rare earth conversion coatings and Mg-rich primers performed poorly in salt fog testing, however, they've performed well on aircraft.	Understood, we will be evaluating the coatings on how they perform for the complete suite of laboratory tests. The three best performing powder coating stack-ups will then be subjected to beachfront testing at the PACAF locations.