UV-Curable Coatings for DOD Aircraft Depot Maintenance (ESTCP Project WP-0804)

Mr. Randy Straw
Concurrent Technologies Corporation (CTC)
June 17, 2010
**UV-Curable Coatings for DOD Aircraft Depot Maintenance (ESTCP Project WP-0804)**

**Perfoming Organization Name and Address**
Concurrent Technologies Corporation,
100 CTC Drive,
Johnstown, PA, 15904

**Sponsoring/Monitoring Agency**

**Distribution/Availability Statement**
Approved for public release; distribution unlimited

**Supplementary Notes**
Presented at the NDIA Environment, Energy Security & Sustainability (E2S2) Symposium & Exhibition held 14-17 June 2010 in Denver, CO.
Overview

• Current processes
• Team and project approach
• Performance baseline/JTP requirements
• Coating selection
• Planned activities/Project timeline
• Summary
• Related Efforts
Current Aerospace Coatings

- Environmental burdens
  - Air Emissions
  - Worker exposure
  - Generate hazardous waste

- Production delays
  - Long cure times
    - 4 hr for primer / 8-72 hr for topcoat
  - Bottlenecks in production
Project Objectives

• **Dem/Val UV-curable aerospace topcoats:**
  – Simple geometry off-aircraft components
  – Interior/exterior flat surfaces
  – Aircraft markings

• **Verify through lab and field testing technology will:**
  – Meet aerospace performance requirements
    • Flexibility
    • Gloss
    • Weatherability
    • Fluid Resistance
  – Reduce environmental burden and costs
  – Increase production throughput
Project Team

**ESTCP Principal Investigator**
Glen Baker

**Principal Stakeholders**
- Ogden Air Logistics Center
- Oklahoma City Air Logistics Center
- Warner Robins Air Logistics Center
- NAVAIR Depot Jacksonville
- USCG Aircraft Repair and Supply Center

**AFRL/RXSC - Program Management**
- Tom Naguy
- Randy Straw (CTC)

**CTC**
- Matthew Campbell, CTC Project Manager
- Anthony Kingera, Technical Support
- Steve Finley, Technical Support

**Coatings Technology Integration Office (CTIO)**
- Lab Testing
  - Corey Bliss

**Subcontractor**
- Bayer Material Science/Deft
Project Approach

Task I – Planning for Demonstration/Validation
• Draft Project Management Plan (PMP) *(completed)*
• Conduct Initial Cost-Benefit Analysis (ICBA) and Performance Baseline *(completed)*
• Draft Joint Test Protocol (JTP) *(completed and approved)*
• Draft Demonstration Plan *(completed and approved)*

Task II – Demonstration/Validation
• Make final selection of coatings for dem/val *(completed)*
• Conduct lab testing and optimization *(in-progess)*
• Conduct field testing *(in-progess)*

Task III – Technology Transition
• Modify specifications and technical orders/manuals
• Purchase/transition equipment to OO-ALC and train staff
• Compare performance versus baseline data
• Prepare Final Cost & Performance and Final Reports
• Prepare Final Briefing
Joint Test Protocol

- MIL-PRF-85285 (minimum) and MIL-PRF-32239 (advanced performance)
  - Adhesion
  - Flexibility
  - Color/gloss match
  - Color/gloss retention
  - Fluid resistance
  - Repairability

<table>
<thead>
<tr>
<th>Appearance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Color</td>
</tr>
<tr>
<td>Gloss</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Adhesion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wet Tape</td>
</tr>
<tr>
<td>Cross Hatch</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Flexibility</th>
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</thead>
<tbody>
<tr>
<td>Low Temperature</td>
</tr>
<tr>
<td>GE Impact</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Resistance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pencil Hardness</td>
</tr>
<tr>
<td>Fluid Resistance</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Accelerated Weathering (Color and Gloss)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Color change (ΔE) of less than 1 after 500 hours; Min gloss of 90 for gloss; max five (5) for flat</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Resistance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heat Resistance</td>
</tr>
<tr>
<td>Humidity Resistance</td>
</tr>
<tr>
<td>Cleanability</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Repairability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scuff sand /Wet Tape</td>
</tr>
<tr>
<td>Scuff sand /Cross Hatch</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Stripability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chemical Strippers</td>
</tr>
<tr>
<td>Dry Media (blasting)</td>
</tr>
<tr>
<td>Laser Stripping</td>
</tr>
</tbody>
</table>
Coating Selection
## COTS Selection Results

<table>
<thead>
<tr>
<th>Coating</th>
<th>Adhesion</th>
<th>Flexibility</th>
<th>Hardness</th>
<th>Fluid Resistance</th>
<th>Weathering</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bayer/Deft</td>
<td>Equals performance of controls</td>
<td>Needs improvement</td>
<td>In desired range</td>
<td>Pass all MIL-PRF-85285 requirements</td>
<td>Passes 3,000 hours for &lt;1 ΔE color change</td>
</tr>
<tr>
<td>Flat Black</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DSM Desotech</td>
<td>Marginal failure on crosshatch</td>
<td>Needs improvement</td>
<td>In desired range</td>
<td>Pass on hardness/adhesion</td>
<td>Needs improvement</td>
</tr>
<tr>
<td>Gloss White</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **Analysis of off-the-shelf coatings**
  - Flat black coatings nearly match controls
  - Gloss coatings require more work
  - Flexibility, gloss, and color retention developmental work
  - Proceed to optimization reformulation
Critical Decisions

• Critical decisions made based on screening testing:
  – Reformulate Bayer/Deft coating to meet one (1) black and two (2) gray colors
  – Reformulate DSM coating to meet two (2) gloss white colors

• Critical decision for cure technology:
  – Coating cure must be made with UVA light (315 – 400nm)
    • UVA required to safely operate light in open maintenance environment
    • UVA requirements more difficult for coating development; DSM Desotech base formulation made for full spectrum cure
  – H&S Autoshot Cure-Tek 1200W lamp used for coating reformulation
    • Intense large area UVA lamp commercially available
# Black/Gray Reformulation Results

**Preliminary JTP Testing Results by Independent Laboratory**

<table>
<thead>
<tr>
<th>TEST</th>
<th>SPECIFICATION</th>
<th>Control Coating</th>
<th>Control Coating</th>
<th>Control Coating</th>
<th>Control Coating</th>
<th>Control Coating</th>
<th>Control Coating</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>36173 Gray (85285)</td>
<td>37038 Black (APC)</td>
<td>36173 Gray (APC)</td>
<td>36173 Gray (UV)</td>
<td>36118 Gray (UV)</td>
<td>37038 Black (UV)</td>
</tr>
<tr>
<td>Delta E from Standard</td>
<td>&lt; 1.0</td>
<td>0.2</td>
<td>1.2</td>
<td>0.2</td>
<td>0.9</td>
<td>10.1</td>
<td>0.9</td>
</tr>
<tr>
<td>60</td>
<td>5 MAX.</td>
<td>3.8</td>
<td>1.1</td>
<td>2.5</td>
<td>4.0</td>
<td>4.3</td>
<td>4.9</td>
</tr>
<tr>
<td>85</td>
<td>9 MAX.</td>
<td>4.0</td>
<td>5.1</td>
<td>3.9</td>
<td>10.1</td>
<td>8.0</td>
<td>11.8</td>
</tr>
</tbody>
</table>

### Adhesion

<table>
<thead>
<tr>
<th>MEK</th>
<th>25 DOUBLE RUBS</th>
<th>Pass</th>
<th>Pass</th>
<th>Pass</th>
<th>Pass</th>
<th>Pass</th>
<th>Pass</th>
</tr>
</thead>
<tbody>
<tr>
<td>WET TAPE</td>
<td>4A OR 5A</td>
<td>5A</td>
<td>5A</td>
<td>5A</td>
<td>2A</td>
<td>4A</td>
<td>3A</td>
</tr>
<tr>
<td>CROSS HATCH</td>
<td>4B OR 5B</td>
<td>4B</td>
<td>4B</td>
<td>3B</td>
<td>4B</td>
<td>5B</td>
<td></td>
</tr>
</tbody>
</table>

### Flexibility

<table>
<thead>
<tr>
<th>GE IMPACT</th>
<th>40% MINIMUM</th>
<th>20%</th>
<th>20%</th>
<th>10%</th>
<th>10%</th>
<th>2%</th>
<th>10%</th>
</tr>
</thead>
<tbody>
<tr>
<td>60 DEG. GLOSS</td>
<td>5 MAX.</td>
<td>3.1</td>
<td>Not Reported</td>
<td>2.3</td>
<td>1.2</td>
<td>1.9</td>
<td>0.9</td>
</tr>
<tr>
<td>85 DEG. GLOSS</td>
<td>9 MAX.</td>
<td>4.6</td>
<td>Not Reported</td>
<td>3.5</td>
<td>4.8</td>
<td>8.6</td>
<td>7.0</td>
</tr>
<tr>
<td>Delta E from Initial</td>
<td>1.0 MAX</td>
<td>0.6</td>
<td>Not Reported</td>
<td>0.1</td>
<td>2.8</td>
<td>1.0</td>
<td>1.0</td>
</tr>
</tbody>
</table>

### Weatherability – 500 Hour Xenon Arc

<table>
<thead>
<tr>
<th></th>
<th></th>
<th>5 MAX</th>
<th>Not Reported</th>
<th>2.3</th>
<th>1.2</th>
<th>1.9</th>
<th>0.9</th>
</tr>
</thead>
<tbody>
<tr>
<td>60 DEG. GLOSS</td>
<td>5 MAX.</td>
<td>3.1</td>
<td>Not Reported</td>
<td>2.3</td>
<td>1.2</td>
<td>1.9</td>
<td>0.9</td>
</tr>
<tr>
<td>85 DEG. GLOSS</td>
<td>9 MAX.</td>
<td>4.6</td>
<td>Not Reported</td>
<td>3.5</td>
<td>4.8</td>
<td>8.6</td>
<td>7.0</td>
</tr>
<tr>
<td>Delta E from Initial</td>
<td>1.0 MAX</td>
<td>0.6</td>
<td>Not Reported</td>
<td>0.1</td>
<td>2.8</td>
<td>1.0</td>
<td>1.0</td>
</tr>
</tbody>
</table>

### Resistance

<table>
<thead>
<tr>
<th>HEAT RESISTANCE</th>
<th>Delta E &lt;1.0</th>
<th>0.1</th>
<th>0.1</th>
<th>0.1</th>
<th>0.9</th>
<th>0.3</th>
<th>0.2</th>
</tr>
</thead>
</table>

### Fluid Resistance

<table>
<thead>
<tr>
<th>INITIAL</th>
<th>Max 2 Pencil Drop</th>
<th>3H</th>
<th>4H</th>
<th>4H</th>
<th>3H</th>
<th>H to 2H</th>
<th>2H to 3H</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mobil Jet 254</td>
<td>24 HR @ 250 F.</td>
<td>3H to 4H</td>
<td>2H to 3H</td>
<td>4H to 5H</td>
<td>F</td>
<td>HB</td>
<td>H</td>
</tr>
<tr>
<td>7808 Lube Oil</td>
<td>24 HR @ 250 F.</td>
<td>5H</td>
<td>4H to 5H</td>
<td>5H</td>
<td>B</td>
<td>B to 2B</td>
<td>B to HB</td>
</tr>
<tr>
<td>Hydraulic Fluid</td>
<td>24 HR @ 150 F.</td>
<td>5H</td>
<td>5H</td>
<td>5H</td>
<td>F</td>
<td>HB to F</td>
<td>F to H</td>
</tr>
<tr>
<td>JP-8</td>
<td>7 DAYS @ 77F.</td>
<td>5H</td>
<td>4H</td>
<td>5H</td>
<td>3B</td>
<td>3B to 2B</td>
<td>F to H</td>
</tr>
</tbody>
</table>

Hardness Scale: 4B < 3B < 2B < B < HB < F < H < 2H < 3H < 4H < 5H
Gloss White Reformulation Results

• DSM Desotech reported following results after approximate 9 month effort:
  – Gloss (did not meet initial 90 at 60 degrees requirement)
  – Adhesion (failure on cross hatch)
  – Weathering (color change over delta 1; but gloss loss <10 at 500 hours)
  – GE Impact Flexibility (unable to meet 10%)
  – Heat resistance (color change over 3 at 1 hr)
  – Opacity (coating was translucent; primer partially visible)
  – Fluid resistance (color change; no adhesion loss for most fluids)
  – **NO CONFIDENCE COATING COULD MEET JTP REQUIREMENTS**

• Based on reported results, following decisions made:
  – DSM Desotech NOT to proceed to JTP testing
  – New subcontract with Bayer/Deft to reformulate gloss white based on lessons learned from Camo Coatings
New Gloss White Effort

• New gloss white coatings effort initiated January 1, 2010
  – Targeting low intensity UVA cure allowing widest possible lamp selection
  – 60 degree gloss of 90+ extremely difficult to hit
  – Approach using waterborne UV-polyurethane dispersion (UV-PUD) to allow low intensity cure, flexible coating, high gloss

• Current progress of best gloss white system:
  – GE Impact flexibility of 60% (higher than reported for any UV coating)
  – 60 degree gloss of 85 (close to requirement of 90)
  – Passes humidity resistance
  – Initial hardness of 2B (needs improvement)
  – Adhesion to primer of 5B
  – Opacity of 96% (95% minimum requirement)
  – Expected completion of formulation and ready for color matching, June 2010
Cure Technology Requirements

• Cure technology critical for successful transition:
  – Demonstration sites surveyed for critical lamp properties
  – Maneuverability needs to exceed commercial model stands
    • Cure area at side of aircraft, underside of wing, or locations close to ground level
    • Ability to mount lamp on standard aircraft maintenance stands
  – Maximize cure area
    • Areas greater than cure area require multiple cure operations

• Class I, Division I Explosion Proof certification requirement for most areas
  – Lamps to be used in aircraft hangars and paint booths
  – Exposure to jet fuel, paint, and other explosion risks
Cure Technology Progress

• Demonstration Lamp Purchased:
  – H&S Auto-shot Cure-Tek 2400W
  – Double-heads allow cure area ~3 square feet
  – Flexible stand for multiple orientations
  – No explosion proof UVA lamp model currently available

• Proposed Implementation Lamp
  – Certified as Class I, Division I explosion-proof
  – Required further development by lamp vendor
  – Explosion-proof model is possible
Demonstration Activities

- **Field application and demonstration - Summer 2010**
  - Time savings
  - Environmental savings
  - Ease of use

- **Monitor aircraft at home stations for one year**
  - Visual appearance
  - Color/gloss stability
  - Adhesion
  - Fluid resistance
## Demonstration Targets

### Hill Air Force Base

<table>
<thead>
<tr>
<th>C-130</th>
<th>F-16</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Escape hatches&lt;br&gt;• Life raft covers&lt;br&gt;• Landing gear door&lt;br&gt;• Rudders&lt;br&gt;• Prop tips&lt;br&gt;• Stenciling</td>
<td>Flaperons&lt;br&gt;Horizontal stabilizers&lt;br&gt;Stenciling</td>
</tr>
</tbody>
</table>

### USCG Elizabeth City

<table>
<thead>
<tr>
<th>HH-60 (primary)</th>
<th>HU-25</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Doors&lt;br&gt;• External fuel tanks&lt;br&gt;• Stenciling</td>
<td>Panel covers&lt;br&gt;Stenciling</td>
</tr>
</tbody>
</table>

### NAVAIR Jacksonville

| • Off-aircraft components<br>• Avionics<br>• Stenciling |
Technology Transition

- Initial transition - Hill AFB
- Update technical documentation
  - General series and weapon system specific technical orders/manuals
  - Performance specifications
- Transition UV application and curing equipment
- Train site personnel
Related Efforts

- Continued evaluation of reformulated UV-curable primers, one-coats, and systems
- Evaluation of UV lamp technology from USAF needs perspective
- UV-curable rain erosion coating technology search
- Large area applications
Summary

• Coatings and potential applications identified
• Reformulation activities underway
• Lab testing and field demonstrations in 2010
• Field evaluation 2010-2011
• Implementation upon successful demonstration
Points of Contact

- **USAF Environmental & Energy Quality Team**
  - Tom Naguy
    - thomas.naguy@wpafb.af.mil  (937) 656-5709
  - Mr. Randy Straw (*CTC*)
    - randall.straw@wpafb.af.mil  (937) 255-5598

- **USAF Coatings Technology Integration Office (CTIO)**
  - Mr. Corey Bliss
    - corey.bliss@wpafb.af.mil  (937) 255-0943

- **Concurrent Technologies Corporation**
  - Mr. Matthew Campbell
    - campbell@ctc.com  (412) 992-5382