

Ultraviolet Curable Powder Coatings With Robotic Curing for Aerospace Applications



Presenter: Mr. Christopher W. Geib,
Science Applications International Corporation
(SAIC)

937.431.4332

geibc@saic.com

Sponsored By: Mr. William Hoogsteden, (937) 656-4223,
USAF, AFRL/RXSSO, WPAFB, OH

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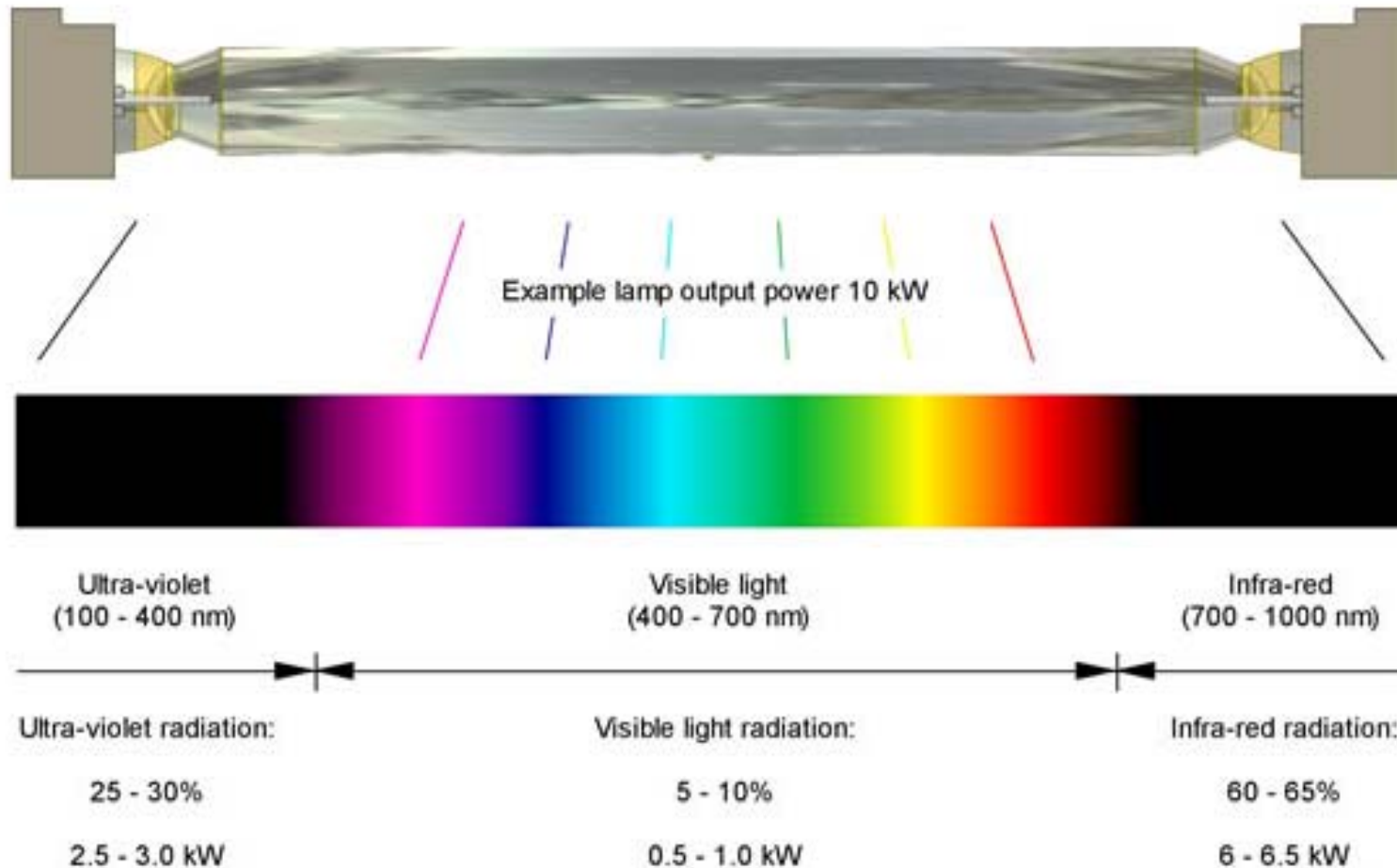
Outline

- UV-Cure Technology
- UV-Curable Powder Coatings Overview
- Robotics as an aid to Curing
- Current Status of ESTCP Project WP-0801



UV Cure Technology

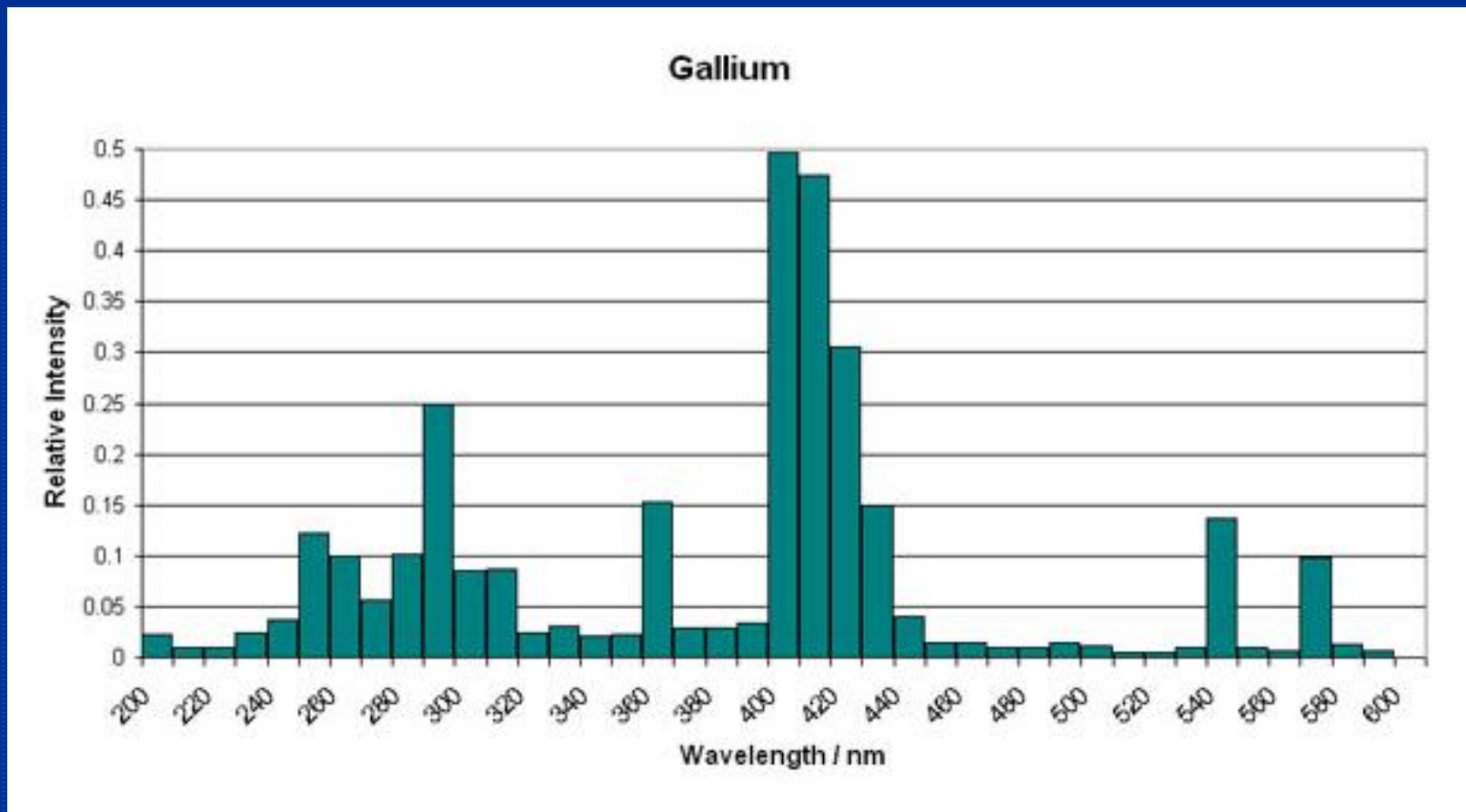
UV Cure Technology



Typical medium pressure mercury discharge lamp power distribution.

UV-Cure Technology

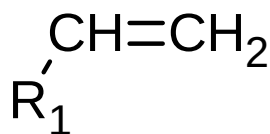
■ Typical Ultraviolet Lamp Spectra:



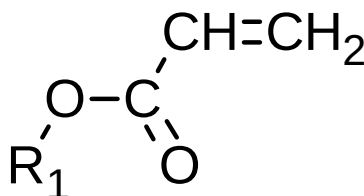
UV Cure Technology

■ Chemistry of UV-cure coatings

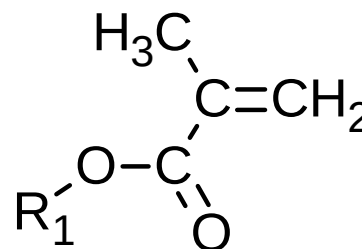
- Can be virtually any polymer matrix used for organic coatings
- The common denominator is the presence of a UV light reactive species on/in the polymer matrix
- Commonly vinyl, acrylate or methacrylate groups



Vinyl



Acrylates



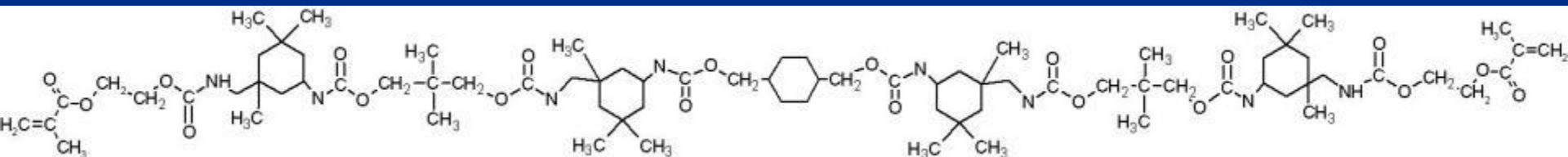
Methacrylates

UV Cure Technology

- Chemistry of UV-cure coatings
 - Typically, the most common UV curable powders are:
 - Polyurethanes
 - Polyesters
 - Epoxies
 - For the UVCPC project, we use a mixture of light activated polyurethanes and polyesters

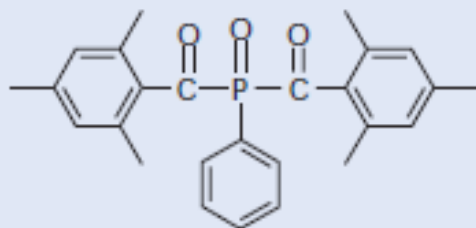
UV Cure Technology

- Polyurethane diacrylate (typical) MW ~2000 - 4000

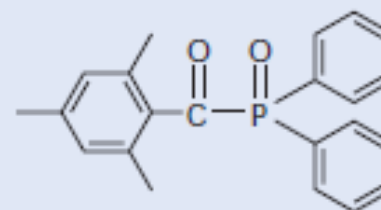


- UV Cure formulations also require:
 - Additives such as pigments and flow agents
 - Photoinitiators

IRGACURE 819 and IRGACURE 819 DW



DAROCUR TPO



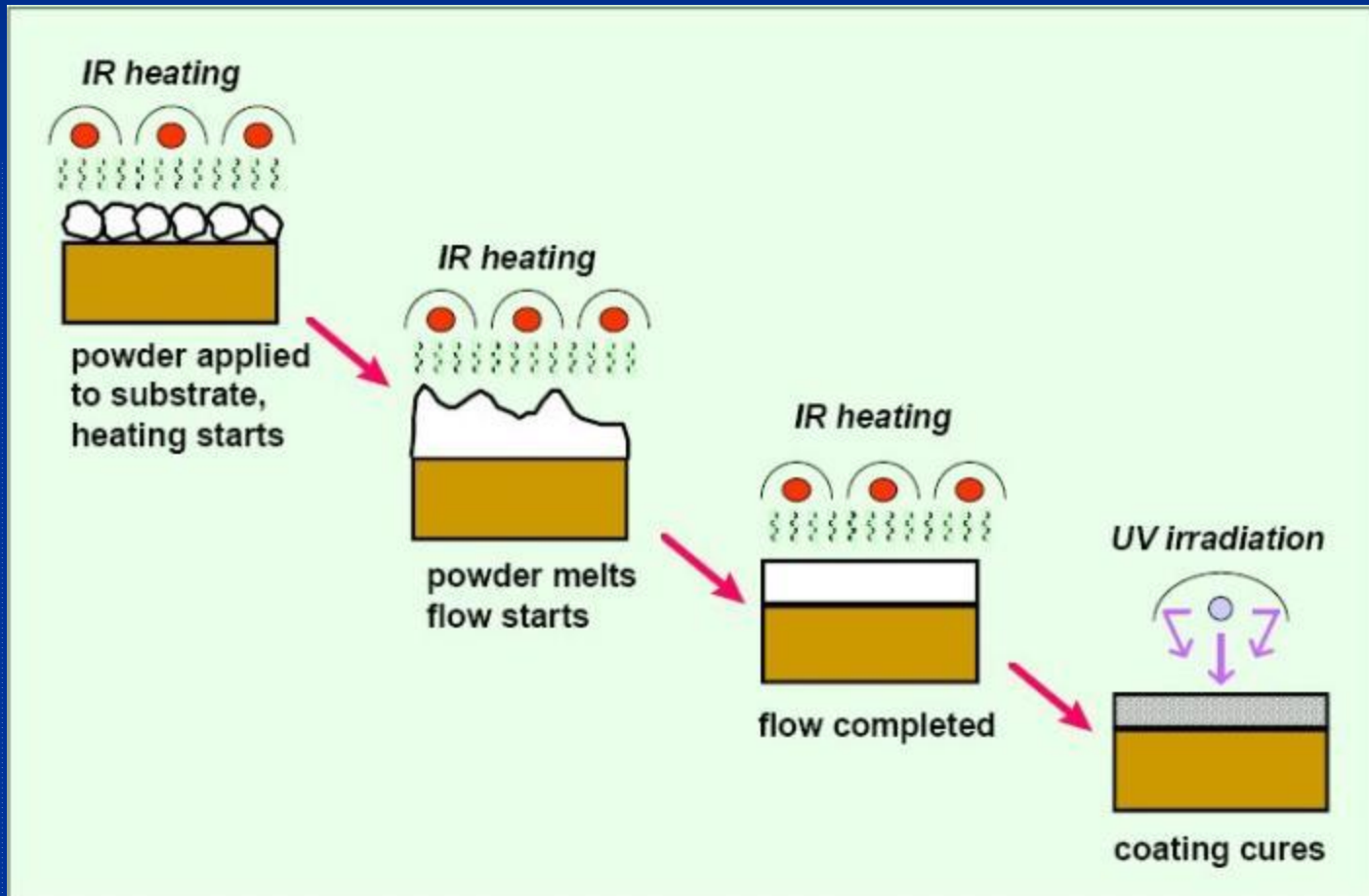
UV Cure Technology



- Powder is applied using electrostatic powder gun
- Applied powder is cured with IR and UV lights mounted on robotic curing system

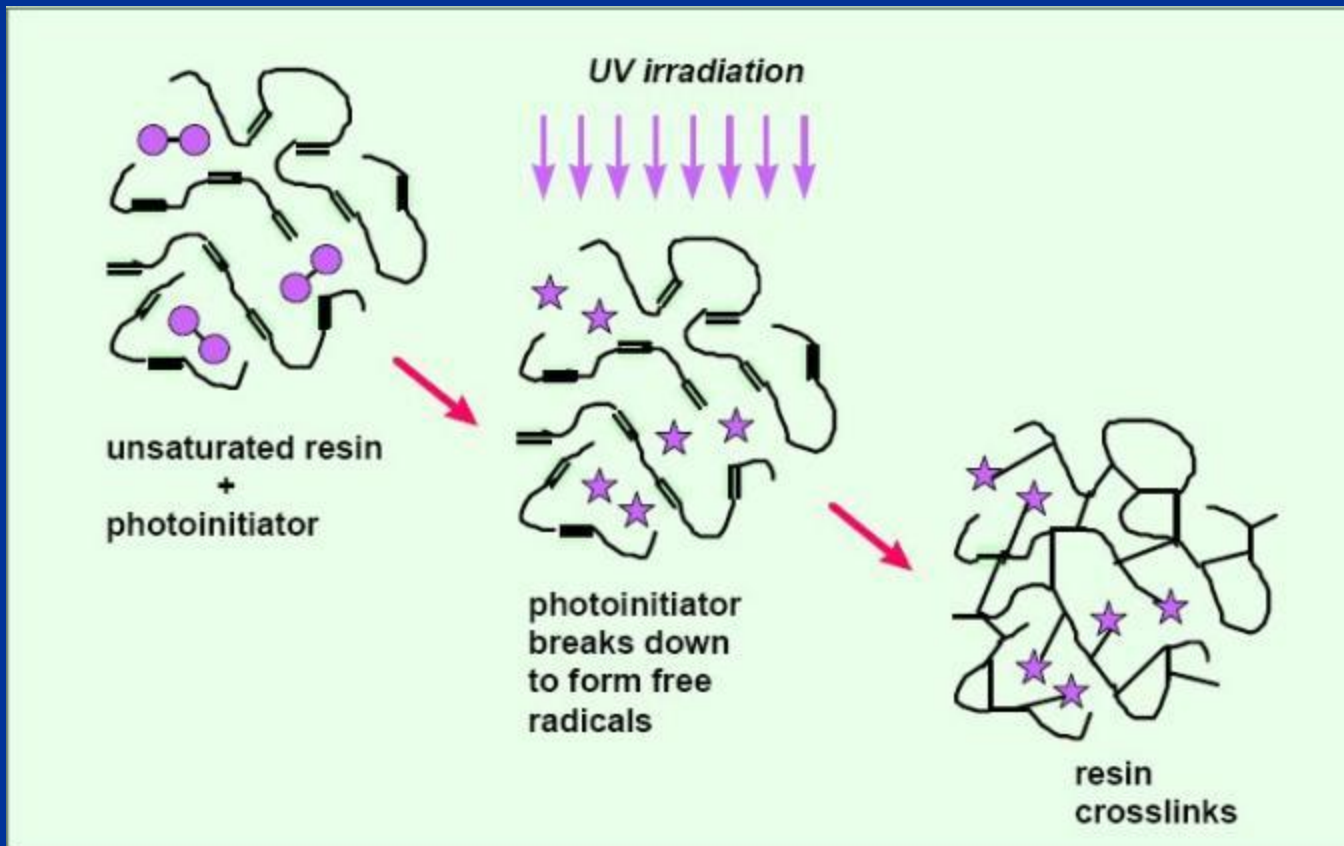
UV-Cure Technology

■ The UV cure powder process:



UV-Cure Technology

- Crosslinking occurs during UV irradiation:



UV-Curable Powder Overview

UV-Curable Powder Overview

- Previous ways of thinking about powder
 - Coating cure temperatures – typically above 220°C
 - Prohibitive for use on tempered metals (Al, Mg, Ti)
 - Prohibitive to use on composites
 - Powder coatings were designed as barrier protection

UV-Curable Powder Overview

- Modern powder coatings can be formulated to have:
 - Lower melt & flow temperatures ($< 110^{\circ}\text{C}$)
 - UV or EB cure functionality can be added
 - Various advanced non-chrome corrosion inhibitors



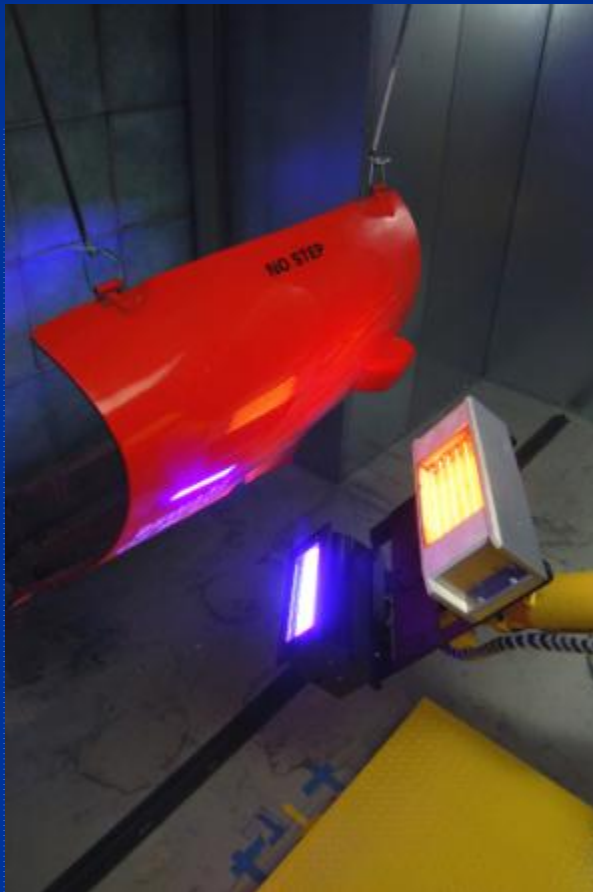
UV-Curable Powder Overview

- Advantages of UV-cure powder coating:
 - Elimination of volatile organics (VOC)
 - Elimination of hazardous air pollutants (HAP)
 - Reduction/elimination of hazardous waste
 - Transfer efficiencies as high as 95% (w/reclaim)
 - Decrease in thermal exposure.
 - Large bulky parts that cannot fit into existing ovens can be coated and cured.
 - UV-cure powder requires less energy because the energy is focused to a specific part only as long as needed.

Robotics as an Aid to Curing

Robotics as an Aid to Curing

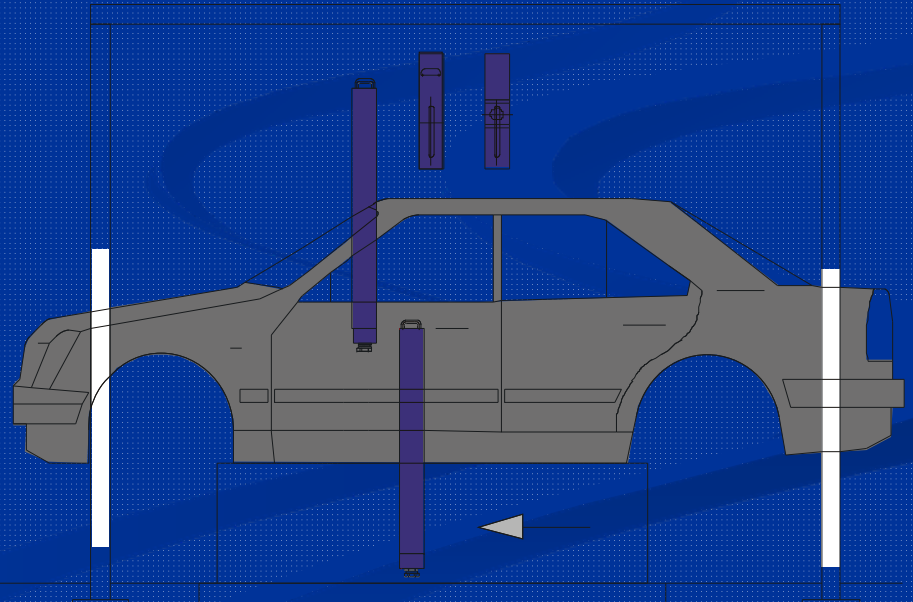
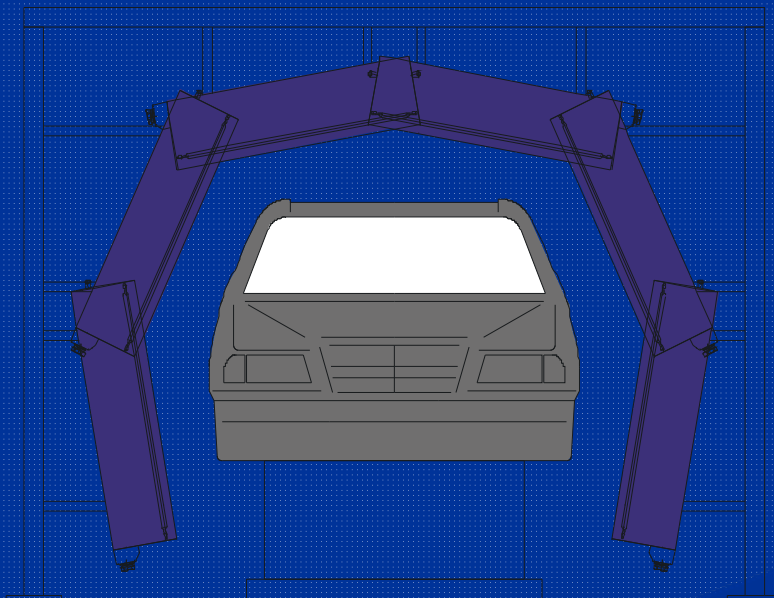
■ Why Use Robots?



■ “Big Bird”

Robotics as an Aid to Curing

- Light tunnel approach using various size UV lamps to optimize cost and exposure



Robotics as an Aid to Curing

■ Drawbacks of fixed lamp approach

■ High Capital Costs

- Lamps, cooling, fixtures, integration

■ High Operating Costs

- Replacement parts
- Energy
- Downtime

■ Technical Adequacy

- Complete cure
- Proper Re-alignment
- Mixed product

Robotics as an Aid to Curing

- Advantages of Robotic Curing
 - Robots ensure repeatability
 - Robots with UV sources can maintain extremely close target distances
 - Robots can be re-programmed in seconds
 - Robotic curing is well suited to large or complex parts
 - Robots eliminate need for many lights

ESTCP Project WP-0801

ESTCP Project WP-0801

■ The Problem:

- DoD spends millions of dollars annually on solvent-based coatings
- Hexavalent chrome primer use still very widespread
- Many topcoats contain hazardous diisocyanates
- Contains or requires volatile solvent use
- Significant hazardous waste costs
- Hazardous materials pose risks to human health and environment
- Process times measured in hours to days

ESTCP Project WP-0801

- The WP-0801 Objectives are:
 - Demonstrate a VOC/HAP-free, diisocyanate free, Ultraviolet cure powder coating (UVCPC) on DoD hardware
 - Demonstrate state-of-the-art robotics for curing



ESTCP Project WP-0801



- Requirements of a UVCPC for military use:
 - Must perform at least as well as MIL-PRF-23377 primer
 - Must also perform as well as MIL-PRF-85285 topcoat
 - Can be prepared in gloss, semi-gloss, and flat finishes



ESTCP Project WP-0801

- The UVCPC is now available in gloss, semi-gloss and a flat finish



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- Robotic Curing System:
 - Robot carries the Infrared and Hg vapor UV lamps



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■ Powders:

- Currently utilizing one vendor
- Two colors, gloss white, semi-gloss and flat gray
- Current powder melts and flows at 120°C
- Will undergo strict validation testing to Mil Standards

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■ Planned demonstration weapon systems:



EA-6B wheels, landing gear



HH-65 helicopter



P-3 wheels, landing gear, radomes



Mk-48 ADCAP torpedo



HC-130 main landing gear doors



A-10 wing

ESTCP Project WP-0801

■ Planned demonstration weapon systems (cont.):



Submarine icecaps



EA-18G wheels, landing gear



Ammunition and storage cases



Submarine communication buoys



Submarine interior components

ESTCP Project WP-0801

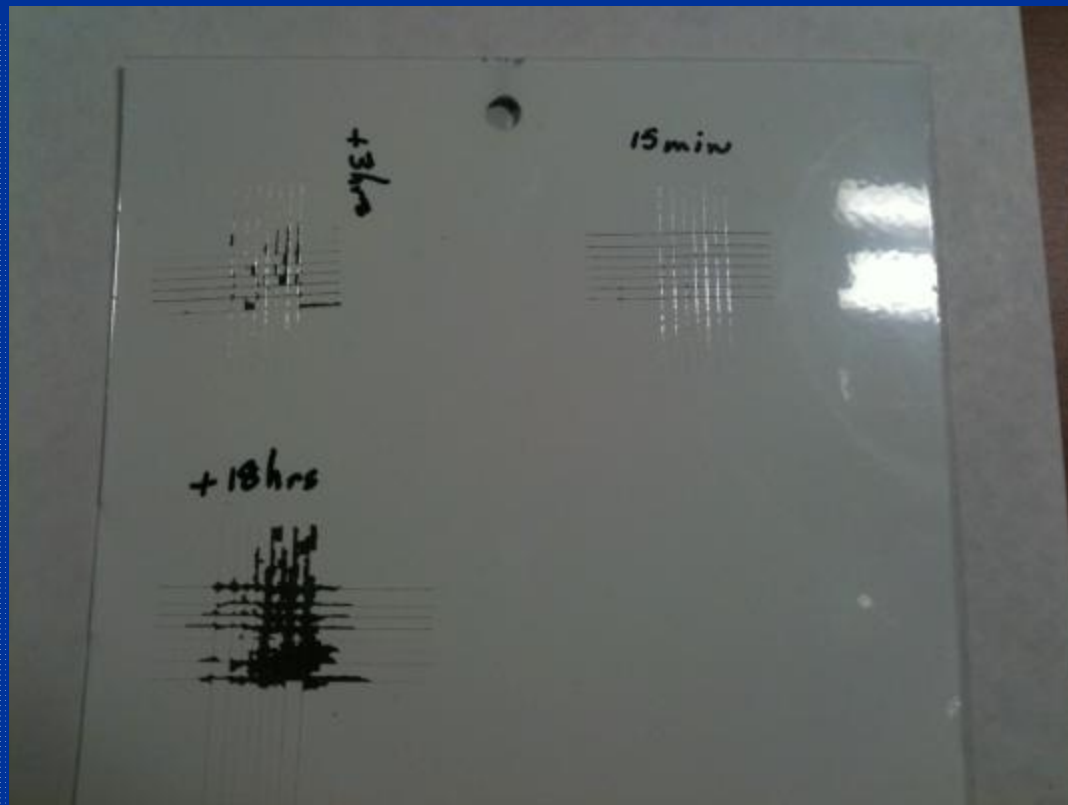
■ Testing:

- Validation testing continues.
- Panels are now at KSC outdoor exposure facility.



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- Issues:
 - Adhesion problem to 2024 alloy aluminum



ESTCP Project WP-0801

■ Issues:

- Adhesion problem to 2024 alloy aluminum
 - Adhesion failures on both Alodine 1600 and PreKote
 - Determined to be based on amount of Copper in alloy
 - Adhesion excellent on low copper alloys and 4130 steel
 - Focused on deoxidizer step, switched from alcoholic phosphoric acid to Turco® 6/16 deoxidizer/etchant
 - Excellent adhesion results over Alodine 1600 (chromate), Alodine 8800 (sol-gel) and Alodine 5200 (Zr chemistry)
 - Fair to poor results over Alodine 1200S (chromate), and Alodine 5900 (tri-chrome)

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■ Issues:

- Initial test results on 1008 steel less than desirable
 - Failed 500 hour SO₂ corrosion test
 - Showing signs of failure after 1 month beach exposure
- Awaiting results on 4130 steel for comparison
- Based on future 4130 results, may require reformulation or primer application for steel components
- Decision TBD

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- Progress:
 - Completed Building 2801 update
 - Facility is ready to receive robotic curing system



ESTCP Project WP-0801

■ Successes:

- Successfully demonstrated capability to UV powder coat and cure on non-conductive materials.
- Successfully created flat finish UVCPC

■ Studies:

- Evaluation of alternative UV sources
- Evaluation of alternative application methods



ESTCP Project WP-0801

- Major Program Milestones:
 - Joint Test Protocol submitted Sept 2008
 - Robot acquired and integration completed
 - Component identification complete
 - Powder and substrates order complete
 - Validation testing continues Apr 2011
 - Draft Demonstration Plan Jan 2011
 - Field Service/Demonstration begins Jul 2011
 - Joint Test Report draft Aug 2011
 - Final Report Mar 2014

Thank You!

Points of contact for UV-curable Powder Coatings ESTCP Project WP-0801:

Mr. William Hoogsteden
Principal Investigator
Air Force Research Laboratory/RXSSO
Wright-Patterson AFB, OH 45433
William.Hoogsteden@wpafb.af.mil
(937) 656-4223

Mr. Christopher W. Geib
Co-Principal Investigator
Science Applications International Corp.
4031 Colonel Glenn Highway
Beavercreek, OH 45431
Christopher.W.Geib@saic.com
(937) 431-4332

Questions?