ESTCP
Cost and Performance Report

(PP-9802)

Demonstration/Validation of a Zero-VOC Waterborne Polyurethane Topcoat

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COST & PERFORMANCE REPORT
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LIST OF ACRONYMS

AEPST	Aviation Environmental Product Support Team
APC	Advanced Performance Topcoat
AQMD	Air Quality Management District
ASTM	American Society for Testing and Materials
CARB	California Air Resources Board
CBA	Cost Benefit Analysis
CHPT	Cherry Point, NC
CNO	Commander of Naval Operations
DoD	Department of Defense
ECAM	Environmental Cost Analysis Methodology
EPA	Environmental Protection Agency
ESH	Environmental, Safety and Health
ESTCP	Environmental Security Technology Certification Program
GSA	General Services Administration
g/l	grams per liter
HAP	Hazardous Air Pollutant
HASP	Health and Safety Plan
HAZMAT	Hazardous Material
HVLP	High Volume, Low Pressure
IPT	Integrated Product/Process Team
ISO	International Organization for Standardization
JAX	Jacksonville, FL
JTP	Joint Test Protocol
JTR	Joint Test Report
MRC	Maintenance Requirement Card
MDR	Maintenance Data Record
MEK	Methyl Ethyl Ketone
MIBK	Methyl Isobutyl Ketone
MILSPEC	Military Specification
NADEP	Naval Aviation Depot
NAVAIR	Naval Air Systems Command
NAVAIRSEFAC	Naval Air Support Equipment Facility
NAWCAD	Naval Air Warfare Center Aircraft Division, Warminster, PA or Patuxent River, MD

LIST OF ACRONYMS (continued)

NESHAP	National Emission Standards for Hazardous Air Pollutants
NORIS	North Island, CA
NPV	Net Present Value
OEM	Original Equipment Manufacturer
P2	Pollution Prevention
PM	Periodic Maintenance
POC	Point of Contact
QA/QC	Quality Assurance / Quality Control
QUV-B	UV-B/Condensation Cyclic Exposure
R&D	Research and Development
ROI	Return on Investment
SCAQMD	Southern California Air Quality Management District
SDLM	Standard Depot-Level Maintenance
SE	Support Equipment
SERDP	Strategic Environmental Research and Development Program
TBD	To Be Determined
TM	Technical Manual
TMS	Type/Model/Series
TO	Technical Order
TRI	Toxic Release Inventory
VOC	Volatile Organic Compound
WR-ALC	Warner Robins Air Logistics Center
WS	Weapons System
ZVOC2	Zero-VOC Topcoat Reformulated for Chalking Resistance

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Army Research Laboratory - Aberdeen Proving Grounds, MD
National Defense Center for Environmental Excellence
Environmental Security Technology Certification Program Office

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1.0 EXECUTIVE SUMMARY

Aircraft painting is a significant source of hazardous waste for the Department of Defense (DoD) and one of Naval aviation's top generators. The Tri-Service Environmental Quality R&D Strategic Plan (Pillar 3: Pollution Prevention, Requirement Thrust: 3.I.4.h: Non-Hazardous Aircraft Paints and Coatings) has identified the finding of replacement materials for painting operations as a high priority. Organic topcoats are the primary source of barrier-type protection against environmental degradation for Navy aircraft, weapon systems (WS) and support equipment (SE). In addition, these materials provide passive countermeasures against many enemy threats. There is a large number of different coating systems currently used by the Navy due to the diverse nature of their functions, the variety of substrates and alloys to which they are applied, and the severe nature of their operational environment. Unlike other DoD applications, Naval aviation topcoats must provide superior protection in a harsh environment with a thin barrier as to minimize weight for proper payload or operations. These coatings contain high volatile organic compound (VOC) contents; VOCs are released during painting operations as hazardous air pollutants (HAPs).

A solution to the problem of using high VOC topcoats has been found. This new topcoat incorporates resins based on novel polymer chemistries into its formulation. These resins are water-dispersible; no organic solvents (i.e. VOCs, HAPs) are necessary for viscosity reduction and subsequent spray application.

The objective of this project was to transfer the zero-VOC topcoat technology information into the hands of future DoD users associated with the painting of military aircraft and ground support equipment. This demonstration/validation stage was full-scale service demonstrations on various aircraft at the Naval Aviation Depots (NADEPs) through coordination with the Lead Maintenance Technology Center for the Environment.

On October 1, 1997, the Environmental Security Technology Certification Program (ESTCP) office funded the Naval Air Warfare Center Aircraft Division in Patuxent River, MD to demonstrate and validate a zero-VOC, waterborne, polyurethane topcoat for use on military aircraft. Successful implementation of this topcoat would result in the elimination of approximately 120 tons of VOCs per year based on General Services Administration (GSA) estimates of MIL-PRF-85285 usage throughout the DoD. The primary objectives of this ESTCP-sponsored project are to eliminate hazardous materials and VOCs in the topcoating process and to maintain the high-performance characteristics found in the current VOC-containing topcoats.

The Joint Test Report (JTR)[1] documents the data and results of the testing to the Joint Test Protocol (JTP)[2], which contains the critical technical and performance requirements and tests necessary to qualify potential alternatives to selected target HAZMATS and processes for a particular application. The JTR is available as a reference for future pollution prevention endeavors by other DoD and commercial users to minimize duplication of effort.

At the demonstration sites, VOCs found in topcoat formulations were identified as the target HAZMATS to be eliminated. VOCs in MIL-PRF-85285C topcoats include methyl ethyl ketone (MEK), methyl isobutyl ketone (MIBK), toluene, and xylene. The topcoats of concern are currently applied by conventional wet-spray and high-volume-low-pressure (HVLP) spray.

Demonstrations were conducted at NADEPs in Jacksonville, FL, Cherry Point, NC, and North Island, CA; at NAVAIRSEFAC in Solomons, MD; at Warner Robins ALC in Warner Robins, GA; and at Sikorsky Aircraft in Stratford, CT. Demonstrations at Cherry Point commenced in 1998; those at North Island, involving partial aircraft painting, and at Solomons commenced in 1999. All others commenced in late 2000 and early 2001. All demonstrations will continue through the end of calendar year 2002.

Two alternatives of the candidate topcoat were tested: gloss white (FED-STD-595 color 17925) and camouflage gray (FED-STD-595 color 36173). Both alternatives passed all but two of the common tests over the three primer systems examined: waterborne epoxy-polyamide, solventborne epoxy-polyamide, and solventborne polyurethane. Blistering was observed in humidity resistance over solventborne primer for the gray. Further examination of the blistered panels determined that the failure was due to the primer; this test was repeated for the gray over solventborne primer from another manufacturer and was passed. This primer was used for all testing of the white. The white topcoat passed all common tests except heat resistance. Of those common tests involving non-primed panels, the only test not passed was impact flexibility with the gray.

Extended tests were used to measure the performance of the candidates versus the standard and to determine certain service-specific characteristics. The results obtained for the gray topcoat showed blistering of both the candidate topcoat and the standard over the waterborne and solventborne epoxy primers. Blistering was also observed for the gray topcoat over solventborne epoxy primer in SO2-modified salt spray and after seven days exposure to de-ionized water at 150 F. Although the average cleaning efficiency was found to be very good, neither the candidate nor the standard met the extended cleanability requirement of 90%. The gray topcoat was determined to be resistant to Skydrol and exhibited excellent low-temperature flexibility by passing the extended mandrel bend requirement. The gloss white topcoat passed all the extended tests that were performed except filiform corrosion resistance, the same as the standard system. Overall, both candidates performed at least as well as the standard topcoat.

Earlier versions of the camouflage topcoat demonstrated limited flexibility and short pot life. This latest formulation has acceptable pot life and outstanding low temperature flexibility, but is still slightly deficient in impact flexibility with the measured value of 20% elongation. Results from operational testing on C-17 and KC-135 aircraft have shown good performance for a topcoat that utilizes fluoro-urethane chemistry to enhance cleanability and weatherability. This coating also exhibited a 20% elongation in the GE impact test. Based on this information and the performance of the gray to the JTP2, it is recommended that the zero-VOC topcoat undergo field-testing on fielded assets. Successful field-testing would support a waiver to the impact flexibility requirement due to the topcoat's outstanding environmental benefits.

The gloss white topcoat exhibited excellent performance but was slightly deficient in heat resistance. It was recommended that it also undergo field-testing away from extreme heat sources until the manufacturer can adjust the formulation, also due to its exceptional environmental benefits, especially for support equipment applications.

The new technology was developed to be a "drop-in" replacement for the standard system; standard operational conditions should have no negative effects. However, greater detail must be given to surface preparation. Currently, the new material costs approximately 25% more than the standard topcoat, due to its experimental nature. Once the material is approved for use, the cost should be comparable to the existing polyurethane topcoat. Because the water is denser than most organic solvents, there is less overspray when using the new topcoat. In addition, two sites reported using approximately 20% less zero-VOC topcoat by volume when painting similar assets with the conventional solventborne topcoat.

These materials will be transitioned to the fleet through technical manual revisions, specification revisions (MIL-PRF-85285C), and aircraft finishing specification (e.g. MIL-STD-7179, T.O. 1-1-8) modifications through Integrated Product Teams (IPT) and the Acquisition Environmental Product Support Team (AEPST). Additional changes will be promulgated through the services' corrosion control manuals (NAVAIR 01-1A-509, T.O. 1-1-691, TM 1-1500-344-23).

2.0 TECHNOLOGY DESCRIPTION

2.1 TECHNOLOGY DEVELOPMENT AND APPLICATION

A zero-VOC topcoat has been developed under a joint Navy-industry effort funded by in full SERDP (Project PP-65). This topcoat, formulated by Deft Coatings, Inc., is based on a novel urethane chemistry that requires no co-solvent. Through manipulation of the polymer backbone chemistry and the evolvement of new surface-active and rheological additives, a water-reducible polyurethane binder system was developed that contains no organic solvents and emits no HAPs. The zero-VOC topcoat offers the potential for the DoD to go beyond environmental compliance in its painting operations.

After achieving "Proof of Principle" for zero-VOC coating technology under SERDP, the project transitioned to ESTCP, whose office funded the Naval Air Warfare Center Aircraft Division in Patuxent River, MD to demonstrate and validate the topcoat for use on military aircraft. Successful implementation of this topcoat would result in the elimination of approximately 120 tons of VOCs per year based on GSA estimates of MIL-PRF-85285 usage throughout the DoD. The primary objective of this ESTCP-sponsored project was twofold: to eliminate hazardous materials and VOCs in the topcoating process and to maintain the high-performance characteristics found in the current VOC-containing topcoats.

2.2 PROCESS DESCRIPTION

The zero-VOC topcoat offers the potential for the DoD to go beyond environmental compliance in its painting operations. This coating evolved from two previous efforts: the first was the development of a waterborne topcoat that had a VOC content of 210 g/l (one-half the maximum allowed VOC for aircraft topcoats) and the other was the investigation of less viscous binder systems for aircraft coatings.

Waterborne or water-reducible coatings are unique in the way that they contain resins that are usually not soluble in water. The resin exists in its own micellar phase. Neutralized carboxylic groups and surfactants stabilize the particle. Excess amine and solvent distribute between the phases. Figure 1 illustrates the resin micelle in a waterborne coating. Since the polymer exists as its own organic phase surrounded by water, the solvent distributes between the organic phase and the aqueous phase. This solvent, called the coalescing solvent, aids in film formation as the water evaporates by allowing binder and pigment particles to fuse into a continuous film.

Formulations based on emulsion, water-reducible and aqueous colloidal dispersions collectively represent one of the most popular alternatives to conventional solventborne coatings. Since water is used as the primary liquid medium or as a diluent, formulations based on waterborne resins have much lower VOC levels than their solventborne counterparts. Recent advances in polymer chemistries have eliminated the need for a coalescing solvent resulting in the formulation of coatings containing no VOCs and substantially less amounts of hazardous materials.

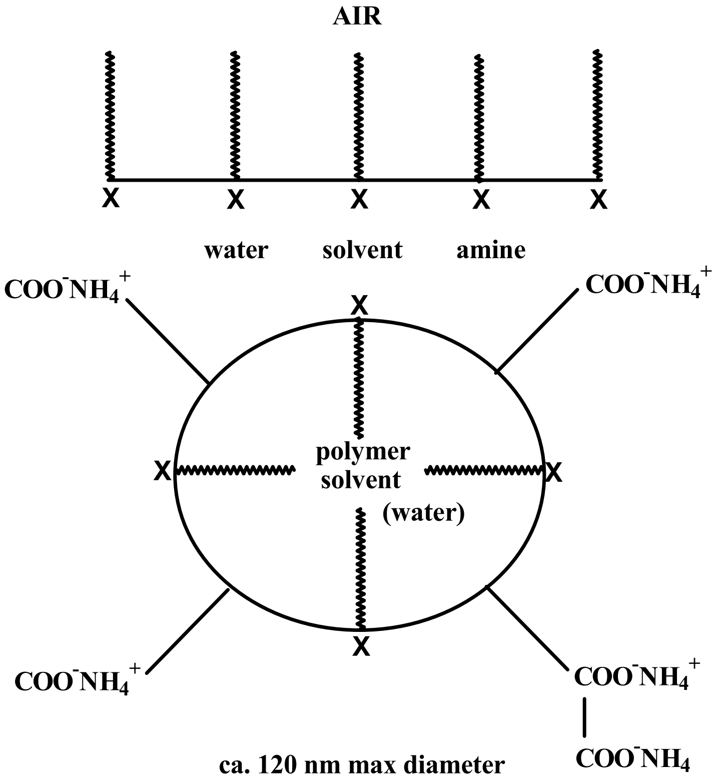

Figure 1. Schematic Diagram of a Polymer Micelle in Water-Reducible Coating.

The Sherwin-Williams Company (formerly Pratt & Lambert) has performed engineering studies to investigate the above resins, formulate coatings from these resins, test, and demonstrate low VOC waterborne topcoats. This study came out of a SERDP project initiated by the Navy in October, 1992. Laboratory evaluations of this topcoat at the Naval Air Warfare Center Aircraft Division (NAWCAD) have indicated that the topcoat meets all the specification requirements. Field demonstrations were initiated on a Navy CH-46 and continue today.

An in-house engineering study at NAWCAD investigated epoxy resins and reactive diluents for formulation into low VOC topcoats. This study also came out of a SERDP project initiated by the Navy in September 1993. Two formulations were determined to meet all the specification requirements for an epoxy topcoat for use on Naval aircraft; the results of this study are published in a technical report.[3]

The results from both of these studies indicated that high-performance topcoats could be developed from water-dispersible, novel polymer resins. The former study validated the use of waterborne technology for formulating coatings and the latter determined that improvements could be achieved through manipulation of polymer backbone chemistry. The success obtained from both projects attests to the feasibility of a zero-VOC topcoat for Naval aircraft applications.

2.3 PREVIOUS TESTING OF THE TECHNOLOGY

The technology was developed and tested in the laboratory under SERDP project PP65. The material was tested to MIL-PRF-85285C. Preliminary results showed deficiencies in post life and flexibility but these issues have since been resolved.

2.4 ADVANTAGES AND LIMITATIONS OF THE TECHNOLOGY

The zero-VOC topcoat offers many advantages; the greatest of these is the elimination of VOCs from the topcoating process. Other advantages include the avoidance of hard emission controls and fines, reduced waste generated costs and waste disposal costs, improved work space/facility environment, and maintenance of the operational readiness of the Fleet.

The main disadvantage of this material is the learning curve associated with the application of a new coating. Waterborne systems have different rheological properties than their solventborne predecessors and application procedures must be modified or changed completely. Therefore, periods of initial downtime will be experienced as workers attend training sessions to become familiar with the new coatings. Also, because most surface contaminants are organic, waterborne systems are more susceptible to pre-paint surface preparation. A zero-VOC coating system would be even more vulnerable to contaminants than previous waterborne systems because the latter contained small amounts of organic solvents. Much more care would have to be taken when preparing an aircraft for painting.

Some earlier versions of waterborne coatings experienced poor drying characteristics, including leveling, gloss, and use time (pot life). However, new dispersing agents and rheology additives have been able to rectify these problems.

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3.0 DEMONSTRATION DESIGN

3.1 PERFORMANCE OBJECTIVES

The new material must, at a minimum, perform comparably to aircraft painted with the standard finishing system within approximately the same time frame. This overall objective was confirmed through coupon testing and in-flight testing as described in the JTP2. For the in-flight evaluation, Navy and Air Force assets were painted with the zero-VOC topcoat at the NADEPs and WR-ALC. Periodic inspections for performance were scheduled with NAWCAD and facility representatives. The zero-VOC topcoat was substituted for the standard topcoat when the asset was scheduled for its final painting at the facility. For more details, refer to the ESTCP Demonstration Plan.[4]

3.2 SELECTION OF TEST PLATFORM/FACILITY

Rework activities utilize aircraft hangars, which provide a controlled environment of the weapon system that is undergoing overhaul. NADEP Jacksonville, FL, for instance, overhauls/reworks cargo-sized aircraft such as the P-3 Orion and the EA-6B Prowler. NADEP Jacksonville processes approximately 50 P-3 aircraft annually. Other military rework activities listed in the above paragraph, process other Type Model Series (TMS) such as the F/A-18, S-3, E-2, and F-14 aircraft at rates equal to or greater in number than the Jacksonville activity. NAVAIRSEFAC is the largest SE rework facility for the Navy and Marine Corps. Implementation of this new technology will eliminate the need for installation of extremely expensive control equipment (i.e. $1M per spray booth for VOC emission control and multi-filter systems for airborne HAPs).

An aircraft or target area of the aircraft (as determined by the JTP[2]) was selected. The chosen asset observed a significant amount of operational exposure in an environment similar to that of the demonstration site (e.g. EA-6B was exposed to the Jacksonville, FL environment: hot, humid summers; mild winters), with some assets going to sea aboard aircraft carriers. See Table 1 for details.

Table 1. Demonstration Site Details.

Site	Asset	Areas Coated
NADEP Jacksonville	EA-6B	Entire aircraft
NADEP Cherry Point	H-46	Access doors and ramp (approximately 100 sq. ft.)
NADEP North Island	OWPs for C-2	Entire wing panel (assembled at NAS Norfolk)
	F/A-18 (2)	Entire aircraft
NAVAIRSEFAC, Solomons	Tow bars Tow tractor Storage van Electric cart Forklift	Entire assets
Warner Robbins ALC	C-141 aft cowlings (6)	Entire assets
	C-130	None to date
Sikorsky Aircraft	H-60	Entire aircraft

3.3 TEST FACILITY HISTORY/CHARACTERISTICS

The test facilities listed above are aircraft rework depots and an original equipment manufacturer (OEM). The environmental impact results largely from the emission of heavy metal compounds and VOCs that are contained in primer and topcoat formulations, which are released during painting operations as HAPs. Despite an 80% reduction in VOC emissions over the past four years NADEPs typically discharge 60,000 pounds of VOCs per year from coatings operations. The costs related to hazardous waste have also risen by more than 20% per year at one NADEP. Hard controls can cost up to \$1M / hangar and fines for non-compliance can be as high as \$25K / day / facility. Downtime also significantly affects force readiness.

3.4 PHYSICAL SET-UP AND OPERATION

The selected aircraft were in the "Standard Depot Level Maintenance" (SDLM) cycle (or equivalent) to minimize impact to operational readiness and costs for removing aircraft from service. The candidate topcoat was applied by the HVLP method. The pressure was set at a minimum of 90 p.s.i., resulting in the maximum pressure of 10 psi at the gun tip.

The aircraft or target areas are currently under test according to Section 3.26 of the JTP[2]. These inspections are being performed at approximate intervals of three months, six months, one year, and two years in accordance with applicable maintenance requirement cards (MRCs). The inspections may also be performed at natural breaks in service such as periods of pre- or post-deployment corrosion inspection, or phase/isochronal maintenance inspections. The areas coated with the candidate system are compared to areas coated with the standard coating system. In the case of an entire aircraft, the comparison is to similar aircraft coated with the standard system at approximately the same time and exposed to a similar environment. Verification such as historical corrosion records, maintenance data reports, and prevention and treatment documentation (MDR-11) may be used for comparison. Acceptable performance shall be at least two years of operational service, including a minimum of two squadron carrier deployments (Navy aircraft), with the candidate material performing at least as well as the standard system (see Section 3.26 of Reference 2). Testing will conclude at the end of calendar year 2002.

Factors such as temperature, relative humidity, application technique, and equipment were noted and documented during the paint application process. Utilization of a tape recorder and camera has ensured accurate and timely collection of data.

3.5 SAMPLING/MONITORING PROCEDURES

Tests were conducted in a manner that eliminated duplication and maximized use of each test coupon. Refer to Section 2 of the JTR.[1]

3.6 ANALYTICAL PROCEDURES

Refer to Section 3 of the JTP.[2]

4.0 PERFORMANCE ASSESSMENT

4.1 PERFORMANCE DATA

Technology demonstrations were conducted at NADEPs in Jacksonville, FL; Cherry Point, NC; North Island, CA; and NAVAIRSEFAC in Solomons, MD. Additionally, Warner-Robins Air Logistics Center, Warner Robins, GA (WR-ALC) was utilized for demonstrations on USAF weapon systems component parts. Current aircraft painting at military depots requires compliance with federal and state environmental regulations. Incorporation of a zero-VOC waterborne topcoat will significantly reduce the VOC evolution from painting operations at these and other sites.

Zero-VOC Topcoat was applied to an H-46 at NADEP Cherry Point, the outer wing panel (OWP) of a C-2 and an F/A-18 at NADEP North Island, condemned aft cowlings from C-141 aircraft at WR-ALC, and an H-60 at Sikorsky Aircraft (Statford, CT). The OWP was painted at North Island and placed on an aircraft at NAS Norfolk, VA. Also, the following pieces of support equipment were painted at NAVAIRSEFAC, Solomons, MD: an electric-powered cart, a tow tractor, eight tow bars, a forklift, and a storage van. Zero-VOC Topcoat was applied to a second F/A-18 at NADEP North Island, an EA-6B at NADEP Jacksonville, and off-aircraft components at WR-ALC.

Once the majority of the JTP tests were passed (see Reference 1), the Navy and the Air Force chose to coat condemned C-141 aft cowlings with the zero-VOC topcoat, the standard aircraft topcoat (MIL-PRF-85285), and an advanced performance fluoro-urethane topcoat. The cowlings were exposed on the south side of the materials building at WR-ALC for 14 months, as shown in Figure 2. The cowlings were washed every 60 days according to the Air Force's T.O. 1-1-8. After the 14 months, chalking was observed on the standard system and the zero-VOC; the worst chalking was present on the zero-VOC. The cause of the chalking had to be determined before applying the coating to deployed assets. Deft believed the chalking was due to the small amount of resin at the surface (necessary for low gloss coatings). A new version was formulated to raise the gloss to just below 5 (maximum gloss allowed for camouflage coatings, see Section 3.8 of Reference 2); this version is designated ZVOC2.

Figure 2. Condemned C-141 Aft Cowlings Exposed at WR-ALC for 14 Months.

A stakeholder meeting was called to propose additional laboratory testing to test the Deft hypothesis. Two tests were proposed: UV-B/condensation cycles (QUV-B) and extended Xe-Arc weathering (Section 3.5 of Reference 2). The QUV-B was chosen because of its severity in the hope that the problem would manifest itself quickly. Xe-Arc weathering more closely resembles natural weathering, but takes a longer period of time to show any discrepancies. Panels exposed to QUV-B were also washed according to T.O. 1-1-8 to determine any deleterious effects from the washing procedure. Xe-Arc-exposed panels were not washed. The three coating systems described in the paragraph above were exposed to both the QUV-B and the Xe-Arc along with ZVOC2.

Although QUV-B exposed panels showed color differences among the standard, zero-VOC, and ZVOC2 after 1,000 hours, it did not represent the behavior observed on the cowlings at WR-ALC after 14 months of outdoor exposure. Values obtained from panels that were subjected to the wash procedure did not vary appreciably (more than 0.3) from those that were unwashed, so it appears that any effects due to cleaning are negligible. However, at 1,500 hours of Xe-Arc exposure, a significant color change was observed on panels coated with the original zero-VOC, indicative of chalking. Much smaller differences were observed after Xe-Arc exposure on the panels coated with the original zero-VOC after 1,500 hours; even smaller color differences were observed on panels coated with the advanced performance topcoat. This behavior did mimic the outdoor exposure of the cowlings at WR-ALC. The standard topcoat and ZVOC2 panels had substantially less color changes after 1,500 hours of Xe-Arc exposure, with ZVOC2 performing somewhat better. It was decided to go forward with the ZVOC2 formulation because the data suggest that it will exhibit less chalking outdoors that the standard material. A summary of the color-change data (see Section 3.5 in Reference 2) after exposure to QUV-B and Xe-Arc artificial weathering is given in Table 2.

Table 2. Color Change Data for the Zero-VOC Topcoats and Other Coatings after Exposure to QUV-B and Xe-Arc Artificial Weathering.

Primer ➔	**Exposure Time (hours)**	**MIL-PRF-2377[a]**		**MIL-PRF-85582, C2, TI[b]**		**MIL-PRF-85582, C1, TII[c]**		**TT-P-2760[d]**	
		QUV-B	Xe-Arc	QUV-B	Xe-Arc	QUV-B	Xe-Arc	QUV-B	Xe-Arc
Topcoat ⇓									
Original Zero-VOC	500	0.33	0.40	0.33	0.47	0.73	0.59	0.44	0.37
	1000	2.10	2.41	3.72	2.09	4.14	2.52	4.33	3.64
	1500	–	6.36	–	5.25	–	5.02	–	7.37
ZVOC2	500	1.81	0.71	1.91	0.61	1.97	0.71	0.55	0.30
	1000	1.81	1.33	2.11	1.40	2.11	1.41	0.66	0.58
	1500	–	1.91	–	1.81	–	1.91	–	1.27
MIL-PRF-85285	500	3.44	2.12	3.68	0.83	3.44	1.71	2.65	1.31
	1000	4.55	2.50	4.16	2.30	4.85	2.20	4.26	2.21
	1500	–	3.01	–	2.62	–	2.71	–	2.51
Advanced Performance Coating	500	0.25	0.32	0.51	0.32	0.32	0.33	0.23	0.17
	1000	0.56	0.46	0.92	0.37	0.62	0.46	0.56	0.37
	1500	–	0.45	–	0.41	–	0.42	–	0.24

[a,d] Refer to Reference 1 for description of primers.

[b] Primer is Class C2, Type I from Deft, Inc. Product number is 44-GN-72.

[C] Primer is Class C1, Type II from Deft, Inc. Product number is 44-GN-8A.

ZVOC2 was used at the other demonstration sites. The high-gloss white was used at NAVAIRSEFAC Solomons, MD and on the C-2 outer wing panels. These assets are currently under test according to Section 3.26 of the JTP. To date, there have been no observed deficiencies. The test criteria and proposed test assets are summarized in Section 5.2 of the final report.[5] The service POCs are responsible for making arrangements with the paint shop and program office personnel, as well as coordinating with the principal investigator for the actual painting of the asset and follow-up inspections. In addition to the EA-6B painted at NADEP Jacksonville, Figures 3, 4, and 5 show other assets painted to date with the zero-VOC topcoat. These also are under test according to Section 3.26 of the JTP and will continue through calendar year 2002.


Figure 3. Zero-VOC Topcoat Application to Outer Wing Panel of C-2 (left) and F/A-18D at NADEP NORIS (right).

Figure 4. CH-60S Helicopter Painted with Zero-VOC Topcoat at Sikorsky Aircraft.

Figure 5. Tow Bars Painted with Zero-VOC Topcoat at NAVAIRSEFAC, Solomons, MD. Tow Bars are Deployed on USS Harry S Truman.

4.2 PERFORMANCE CRITERIA

The primary performance criteria are the common tests listed in the JTP[2]. More details can be found in Section 2.1 of the JTR.[1]

4.3 DATA EVALUATION

Two alternatives of the candidate topcoat were tested: gloss white (FED-STD-595 color 17925) and camouflage gray (FED-STD-595 color 36173). Both alternatives passed all but two of the common tests over the three primer systems examined: waterborne epoxy-polyamide, solventborne epoxy-polyamide, and solventborne polyurethane. Blistering was observed in humidity resistance over solventborne primer for the gray. Further examination of the blistered panels determined that the failure was due to the primer; this test was repeated for the gray over solventborne primer from another manufacturer and was passed. This primer was used for all testing of the white. The white topcoat passed all common tests except heat resistance. Of those common tests involving non-primed panels, the only test not passed was impact flexibility with the gray.

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Earlier versions of the camouflage topcoat demonstrated limited flexibility and short pot life. This latest formulation has acceptable pot life and outstanding low temperature flexibility, but is still slightly deficient in impact flexibility with the measured value of 20% elongation. Results from operational testing on C-17 and KC-135 aircraft have shown good performance for a topcoat that utilizes fluoro-urethane chemistry to enhance cleanability and weatherability. This coating also exhibited a 20% elongation in the General Electric impact test. Based on this information and the performance of the gray to the JTP2, it is recommended that the zero-VOC topcoat undergo field-testing on fielded assets. Successful field-testing would support a waiver to the impact flexibility requirement due to the topcoat's outstanding environmental benefits.

The gloss white topcoat exhibited excellent performance but was slightly deficient in heat resistance. It was recommended that it also undergo field-testing away from extreme heat sources until the manufacturer can adjust the formulation, also due to its exceptional environmental benefits, especially for support equipment applications.

Refer to Sections 4.5 and 5.0 of the JTR.[1] The results summarized in the JTR and those tests described in Section 4.1 above should provide the stakeholders the confidence that the zero-VOC topcoats will perform as expected. Overall, the new technology performed at a comparable level to the standard topcoat. Field tests are still underway.

4.4 TECHNOLOGY COMPARISON

The technical performance of the zero-VOC topcoat was compared to the standard aircraft topcoat, which conforms to MIL-PRF-85285. Results are summarized in the JTR[1] and are discussed in Section 4.3 above.

The zero-VOC topcoat was also compared to an advanced performance topcoat (APC), which is based on novel fluoro-urethane resin chemistry. The APC exhibited superior resistance to artificial weathering, as shown in Table 2, and is expected to extend the life of aircraft topcoats from three to four years to eight years. The environmental benefit to the APC is reduced number of repaint cycles and field touch-up.

Presently, the APC is formulated at 420 g/l (maximum VOC allowed for compliance). MIL-PRF-85285 specification testing at NAWCAD revealed some discrepancies with the APC. Gloss white specimens: (A) became heavily stained when subjected to lubricating oil (Reference 2, Section 3.12); (B) blistered when exposed to humidity resistance test (Reference 2, Section 3.11); and (C) underwent a significant color change when subjected to heat (E of 4.8, Reference 2, Section 3.9). Camouflage gray specimens: (A) exhibited poor cleanability (Reference 2, Section 3.6) and (B) marginal flexibility with a 20% elongation in impact flexibility (Reference 2, Section 3.14). NAWCAD has proposed a five-year project under the Future Naval Capabilities - Total Ownership Cost Program to improve this promising technology and take advantage of its superior resistance to UV while lowering the VOC content.

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5.0 COST ASSESSMENT

5.1 COST REPORTING

An Impact Analysis was performed to evaluate the zero-VOC topcoat compared to conventional topcoats at multiple sites throughout the Navy. A summary is provided in Section 5.3. The analysis compares the annual economic and environmental considerations of the proposed alternative versus the existing process. The implementation of the alternative at the various sites will achieve the goal of reducing or eliminating the hazardous effects of current topcoats.

The Impact Analysis develops cost-benefit information, including quantitative assessments of the environmental benefits of reducing hazardous products, priority chemicals, and hazardous waste. These metrics are developed by modeling hazardous material, emission, and waste reductions from process changes and material substitutions. Cost-benefit measures show the economic sensitivity to changes in site or technical variables. The standardized cost-benefit analysis and return-on-investment procedures generate defensible cost data for pollution prevention (P2) technology programs. Pollution prevention investments differ from other investment opportunities available to NAVAIR, in that savings from P2 projects are often realized in cost areas that may be aggregated within the installation's overhead accounts, and benefits include improved regulatory compliance, worker health, and community relations. As a result, the impact of potential P2 projects is frequently underestimated. The requirements for standard analyses are derived from Office of Management and Budget (OMB) Circular A-11, *Planning, Budgeting, and Acquisition of Capital Assets (Part 3)*, includes the *Capital Planning Guide*, which invokes OMB Circular A-94 on use of discount rates in cost-benefit analyses, and Environmental Cost Analysis Methodology (ECAM) Handbook. Circular A-94, *Guidelines and Discount Rates for Benefit-Cost Analysis of Federal Programs*, Section 5, states that Net Present Value is the preferred decision criterion. The Navy also provided an update to the equipment depreciable life guidance, in a 26 Mar 98 memo from the Office of the Under Secretary of Defense, Comptroller, *"Policy for the Depreciation of DoD General Property, Plant, and Equipment Assets"*. The memo issued policy to set the equipment depreciable life period used in these analyses at 12 years.

5.2 COST ANALYSIS

An enterprise-wide analysis has to account for the variations in workload, regulations, equipment, and business factors at each potential site that could use the new process. In the past, it has been commonplace to determine an average or mode to account for site variations, do the analysis, and either adopt or reject the technology for all sites under consideration based on results for a "typical" site. However, the analysis performed is a multi-site analysis, which yields a list of the chosen sites where the alternative has positive economic benefits. A "baseline" site is chosen as an example of the cost and benefits to a single site; normally for NAVAIR the site used is the depot site most likely to implement the alternative first. In this analysis, the "baseline" site was chosen to be NADEP Jacksonville. The "summary" of the sites is the cost and benefits of all sites recommended, "selected sites", for deployment because of the positive economic benefits. Therefore, the results shown for the selected sites will be the overall benefit to the Navy if the zero-VOC topcoat is transitioned to the sites that yield a positive return. This methodology includes sensitivity analyses that help find the optimum economics and environmental benefit for alternative deployment scenarios.

- The *payback* (in years) shows how quickly the Navy could realize recovery of the investment. If there are no investment costs for the new technology as is the case for this topcoat replacement, and the annual savings is positive, there will always be an "immediate" payback on the investment.

- The *net present value* shows the total cash benefit in today's dollars of the investment, and is the best economic metric to compare alternatives to each other. Some technologies are a material or business practice change only, and hence do not entail an investment by the facility or using command; therefore, there is no payback or Internal Rate of Return (IRR), so the only useful economic metric is net present value. The net present value is determined for an investment life of 12 years.

- The *TRI chemical reduction* (annual) shows the amount of chemicals (lbs) on the Superfund Amendment and Reauthorization Act (SARA) Title III list that would be reduced from release into the environment. The analysis includes two charts showing reductions at the baseline site, and reductions for the enterprise wide deployment.

- The *HazMat reduction* (annual) shows the reduced amount of material inventory containing the TRI chemicals, indicating reduced hazardous material inventory control and Toxic Release Inventory (TRI) reporting workload.

- The *Hazardous Waste reduction* (annual) shows the reduced amount of waste disposal, indicating reduced contract services costs, waste handling and reporting, and associated risks.

5.3 COST COMPARISON

The results of Impact Analysis are shown in Table 3. The results indicate that the Zero-VOC Topcoat yields positive economic and environmental benefits at the "Baseline" site, NADEP Jacksonville. NADEP Jacksonville will yield an annual savings of $37,084. Since there are no investment costs to implement the technology and the annual savings is positive, NADEP Jacksonville will yield an "Immediate" payback. NADEP Jacksonville will also realize a reduction of 8,812 pounds of hazardous waste per year. NOTE: The technology assumptions used in the Impact Analysis are presented in Appendix B.

Table 3. Summary of the Results from Impact Analysis.

	Hazardous Material Reduction (lb)	Hazardous Waste Reduction (lb)	TRI Chemical Reduction (lb)	VOC Chemical Reduction (lb)	Payback (yr)	Annual Savings ($)	Net Present Value (over 12 years) ($)
Baseline (NADEP JAX)	1,898	8,812	4,182	7,546	Immediate	$37,084	$407,499
65 Selected Sites (Table 5-2)	31,222	144,950	68,798	122,770	Immediate	$848,019	$9,450,335

Table 3 also shows a summary of the economic and environmental benefits of the selected sites. The selected sites were downselected from a list of 66 proposed sites including NADEP Jacksonville. The only site not selected because it did not yield positive economic and environmental benefits was NAF Washington. Table 4 shows the "selected sites" or the sites that yielded positive economic benefits with the implementation of the Zero-VOC Topcoat. The "selected sites" realize an "Immediate" payback as well as an annual savings of $848,019 combined. The "selected sites" effectively show the actual Navy-wide benefits by implementing the Zero-VOC Topcoat at the appropriate sites.

Table 4. List of "Selected Sites."

Sites Selected for Technology Deployment
NADEP JAX (Baseline)
MCAS CAMP PENDLETON
MCAS CHERRY POINT
MCAS FUTENMA
MCAS IWAKUNI
MCAS KANEOHE
MCAS MIRAMAR
MCAS NEW RIVER
MCAS QUANTICO
MCAS YUMA
NADEP CP
NADEP NI
NAF ATSUGI
NAF CHINA LAKE
NAF SIGONELLA
NAS AGANA
NAS ATLANTA
NAS BARBERS PT
NAS BRUNSWICK
NAS CORPUS CHRISTI
NAS FALLON
NAS FORT WORTH
NAS GUANTANAMO
NAS JACKSONVILLE
NAS KINGSVILLE
NAS LEMOORE
NAS MERIDIAN
NAS NEW ORLEANS
NAS NORFOLK
NAS NORTH ISLAND
NAS OCEANA
NAS PATUXENT RIVER
NAS PENSACOLA
NAS POINT MUGU
NAS WHIDBEY IS
NAS WILLOW GROVE
NS KEFLAVIK
NS MAYPORT
NS ROTA
NS YOKOSUKA
NSRDL PANAMA CITY
USS A LINCOLN CVN-72
USS AMERCIA CVA-66
USS BELLEAU WOOD
USS BOXER LHD-4
USS CARL VINSON CVN-70
USS CONSTELLATION 64
USS EISENHOWER CVN-69
USS ENTERPRISE CVAN-65
USS ESSEX LHD-2
USS G WASHINGTON
USS GUAM
USS INCHON
USS INDEPENDENCE CV-62
USS KEARSARGE LHD-3
USS KITTY HAWK CVA-63
USS NASSAU
USS NEW ORLEANS
USS NIMITZ CVAN-68
USS PELELIU LHA-5
USS SAIPAN
USS T ROOSEVELT
USS TARAWA
USS WASP

Table 5 breaks down the annual operating costs and shows where the annual cost savings of $37,084 for NADEP Jacksonville and $848,019 for the "selected sites" is recognized. NADEP Jacksonville and the "selected sites" both realize increased material procurement costs for the new alternative, while the labor associated with each process is unchanged. Both NADEP Jacksonville and the "selected sites" realize an annual savings from maintenance, utility, services, and facility costs with the Zero-VOC topcoat alternative.

Table 5. Breakdown of Annual Operating Cost.

Cost Elements	Baseline (NADEP Jacksonville)		Summary of Selected Sites	
Annual Operating Costs	Current Topcoat	Zero-VOC Topcoat	Current Topcoat	Zero-VOC Topcoat
Materials	$97,215	$100,473	$1,599,193	$1,652,773
Labor	$431,347	$431,347	$936,854	$936,854
Maintenance	$25,000	$2,500	$616,667	$61,667
Utility	$900	$90	$22,200	$2,220
Services	$18,268	$6,637	$303,782	$110,363
Facility (ESH)	$6,000	$600	$148,000	$14,800
TOTAL ANNUAL OPERATING COST	$578,731	$541,646	$3,626,696	$2,778,677
ANNUAL SAVINGS		$37,084		$848,019

Table 6 presents the resource consumption table for the current and proposed processes. Each of the resources is consumed at a given rate, which acts as the driver. The drivers are the rate at which the resources are consumed by the activity. Therefore, the resource drivers identify the relationship of the resource consumption during each activity.

Table 6. Resource Consumption for Current and Proposed Topcoats for Both NADEP Jacksonville and the "Selected Sites."

	Baseline (NADEP Jacksonville)		Summary of Selected Sites	
	Estimated Annual Quantity		Estimated Annual Quantity	
Resource	Current Topcoat	Zero-VOC Topcoat	Current Topcoat	Zero-VOC Topcoat
Workload Replaced with Proposed	0	457,067	0	7,518,747
Workload Remaining with Current	507,852	50,785	8,354,163	835,416
Solvent paint req'd (gal)	1,413	141	23,251	2,325
Zero VOC paint req'd (gal)	0	1,272	0	20,926
Thinner/Purge Solvent (gal)	353	99	5,813	1,628
lbs paint & thinner (lbs)	17,149	15,251	282,099	250,876
Solvent painting labor (hrs)	8,329	833	137,008	13,701
Zero VOC Labor (hrs)	0	7,496	0	123,307
Total amount of hazardous waste (lbs)	13,839	5,028	227,658	82,708
# of Dry Filter Booths	3	0.3	74	7.4

Tables 7 and 8 provide the direct process costs for the current and proposed topcoats for NADEP Jacksonville and the “selected sites”, respectively. This table indicates the annual cost associated with each resource consumed during an activity.

Table 7. Direct Process Costs for Current and Proposed Topcoats for NADEP Jacksonville.

Baseline	Estimated Annual Quality		Cost Factor	Annual Cost	
Resource	**Current Topcoat**	**Zero-VOC Topcoat**		**Current Topcoat**	**Zero-VOC Topcoat**
Solvent paint req’d (gal)	1,413	141	$66.14	$93,485	$9,349
Zero VOC paint req’d (gal)	0	1,272	$70.40	$0	$89,557
Thinner/Purge Solvent (gal)	353	99	$8.13	$2,873	$804
Solvent painting labor (hrs)	8,329	833	$51.43	$428,349	$42,835
Zero VOC Labor (hrs)	0	7,496	$51.43	$0	$385,514
Hazardous Waste Disposal	13,839	5,028	$1.32	$18,268	$6,637
VOC Equipment Annual PM	3	0.3	$8,333.33	$25,000	$2,500
VOC Energy	3	0.3	$300.00	$900	$90
				$568,875	**$537,286**

Table 8. Direct Process Costs for Current and Proposed Topcoats for the “Selected Sites.”

Summary of Selected Sites	Estimated Annual Quality		Cost Factor	Annual Cost	
Resource	**Current Topcoat**	**Zero-VOC Topcoat**		**Current Topcoat**	**Zero-VOC Topcoat**
Solvent paint req’d (gal)	23,251	2,325	$66.14	$1,537,830	$153,783
Zero VOC paint req’d (gal)	0	20.926	$70.40	$0	$1,473,214
Thinner/Purge Solvent (gal)	5,813	1,628	$8.13	$47,259	$13,232
Solvent painting labor (hrs)	32,250	3,225	$27.52	$887,532	$88,753
Zero VOC Labor (hrs)	0	29,025	$27.52	$0	$798,778
Hazardous Waste Disposal	227,658	82,708	$1.33	$303,782	$110,363
VOC Equipment Annual PM	74	7.4	$8,333.33	$616,667	$61,667
VOC Energy	74	7.4	$300.00	$22,200	$2,220
				$3,415,268	**$2,702,010**

Tables 9 and 10 present the indirect process costs for the current and proposed topcoats for the "Baseline" site, NADEP Jacksonville and the "selected sites", respectively.

Table 9. Indirect Costs for Current and Proposed Topcoats at NADEP Jacksonville.

Baseline	Estimated Annual Quality			Annual Cost	
Resource	**Current Topcoat**	**Zero-VOC Topcoat**	**Cost Factor**	**Current Topcoat**	**Zero-VOC Topcoat**
Indirect Materials	17,149	15,251	$0.05	$857	$763
Indirect Labor	8,329	8,329	$0.36	$2,998	$2,998
Permit	3	0.3	$2,000.00	$6,000	$600
				$9,856	**$4,361**

Table 10. Indirect Costs for Current and Proposed Topcoats at the "Selected Sites."

Summary of Selected Sites	Estimated Annual Quality			Annual Cost	
Resource	**Current Topcoat**	**Zero-VOC Topcoat**	**Cost Factor**	**Current Topcoat**	**Zero-VOC Topcoat**
Indirect Materials	282,099	250,876	$0.05	$14,105	$12,544
Indirect Labor	137,008	137,008	$0.36	$49,323	$49,323
Permit	74	7.4	$2,000.00	$148,000	$14,800
				$211,428	**$76,667**

As well as having many economic benefits shown above, the zero-VOC topcoat alternative also provides many environmental benefits. Figure 6 shows the comparison of specific VOC chemicals associated with the current and new topcoats for the "selected sites". The quantities shown on the figures are a summary of the results for all of the "selected sites". The new quantity legend is for zero-VOC topcoat, and the current quantity legend is for the current topcoat, respectively. Figure 7 shows a comparison of the specific TRI chemicals used in each alternative. Overall, the zero-VOC alternative would provide a significant reduction in VOC and TRI chemicals at the 65 "selected sites" throughout the Navy as shown below.

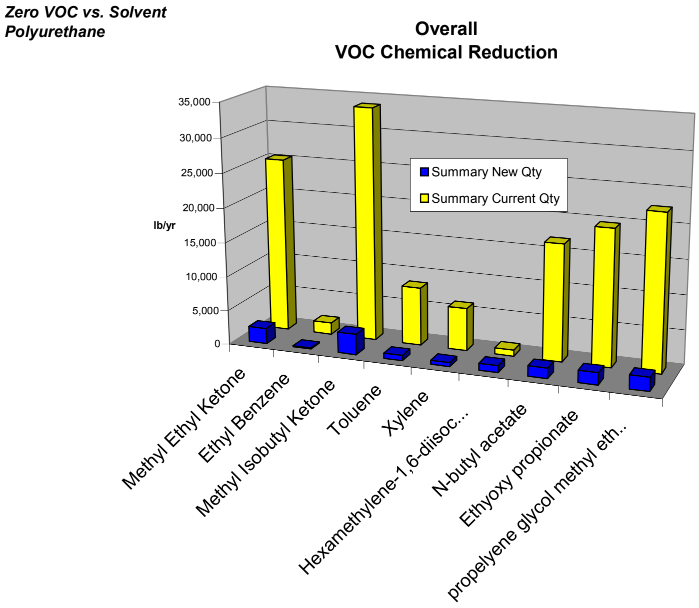

Figure 6. Summary of VOC Chemicals.

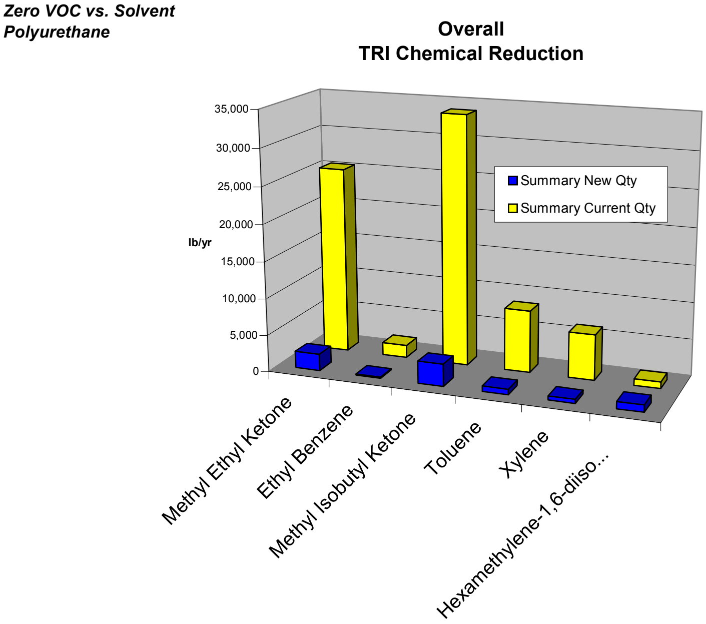

Figure 7. Summary of TRI Chemicals.

This study analyzed 12 aircraft platforms at 65 selected sites, for a total of 3,785 aircraft. Figure 8 shows the economic benefits, which could potentially be realized by each platform over the next 12 years if the zero-VOC topcoat alternative is implemented. The biggest winner is the F/A-18 platform, which would realize a Net Present Value of $2,420,366. The other big winners that make up roughly 50% of the economic benefit when combined with the F/A-18 platform are the H-46 and H-53 platforms.

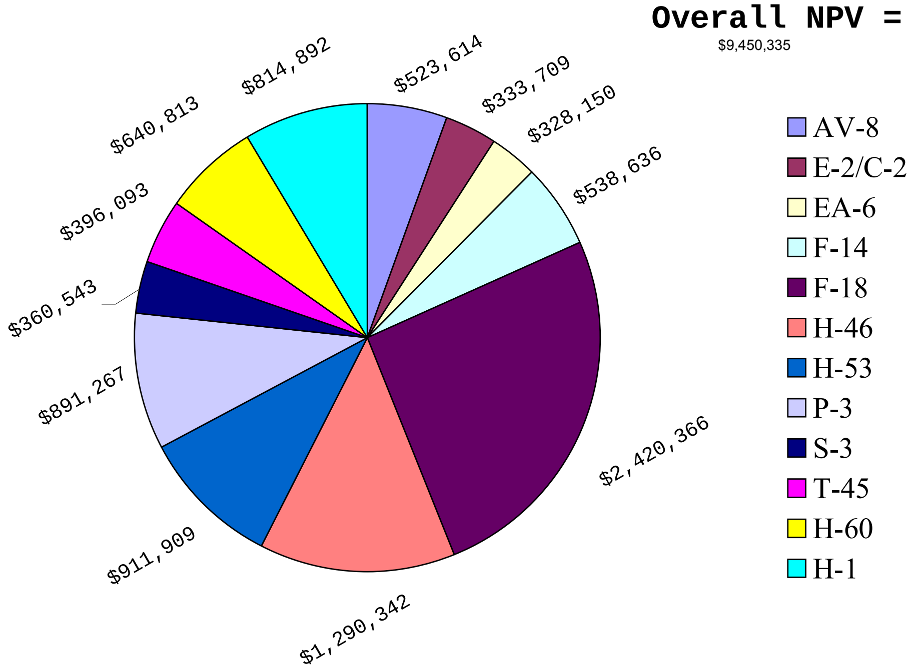

Figure 8. Net Present Value by Aircraft Platform.

6.0 IMPLEMENTATION ISSUES

6.1 COST OBSERVATIONS

The new technology was developed to be a "drop-in" replacement for the standard system; standard operational conditions should have no negative effects. However, greater detail must be given to surface preparation (see Section 2.4). Currently, the new material costs approximately 25% more than the standard topcoat, due to its experimental nature. Once the material is approved for use, the cost should be comparable to the existing polyurethane topcoat. Because the water is denser than most organic solvents, there is less overspray when using the new topcoat. In addition, two sites reported using approximately 20% less zero-VOC topcoat by volume when painting similar assets with the conventional solventborne topcoat.

The cost performance criteria addressed economic as well as environmental issues and was performed from a corporate point-of-view (i.e., how does this technology impact all of DoD).

Cost performance information is essential to program for current and future P2 projects. Furthermore, the impact analysis has supported the Acquisition Support Process as outlined in the NAVAIR Corporate Environmental Management Plan. Phase 2 of the Acquisition Support Process requires the establishment of solutions and to set a course of action in addressing operational requirements. In Phase 3, the sponsor will support the proposed solutions that will have the greatest benefit to the acquisition community. Impact studies and analysis have supported both phases of the decision making process. This approach has streamlined the project line built on a firm justification foundation, ultimately providing better products and better serving the end customer.

6.2 PERFORMANCE OBSERVATIONS

The new coating is designed as a substitute for the high-solids polyurethane topcoat that conforms to MIL-PRF-85285. A one-for-one substitution is proposed; however, the following preparation is required before the material can be applied successfully.

The zero-VOC topcoat is a two-part system consisting of a pigmented polyol resin and an isocyanate-based curing agent. The two components are combined by hand or low-speed mechanical mixer. No high-speed mixing or paint shakers should be used at any time during the mixing process. After the components are thoroughly blended, the mixture is thinned to a viscosity of 18-20 seconds as measured by a #4 Ford cup with de-ionized water.

The admixed coating may be applied by conventional or high-volume, low-pressure (HVLP) spraying techniques. If HVLP is to be utilized, a high line pressure (about 90 psi) should be used to provide the maximum amount of atomization. Smaller droplets coalesce more easily than larger ones, resulting in a more uniform, smoother finish. Application methods such as plural component should be avoided as they use high shear forces to combine the two parts in the paint line.

Before any activity sprays the zero-VOC coating, the artisans should receive a day's training to effectively apply the material. This training is available from NAWCAD and Deft, Inc. All specifics will be documented in the specification and technical manual updates.

Because the zero-VOC topcoat will be used at sites that exhibit ranges of climates and painting conditions, it was necessary to determine the curing conditions at various temperatures and relative humidities. Elevated temperature cure studies were conducted to determine a procedure for accelerated curing of the zero-VOC topcoat. These studies are of interest to some component shop and support equipment activities that need to paint and cure in batches within designated shifts. Following the procedure for elevated cures may cause the coating to have small runs and drips. If these are unacceptable, it is recommended that accelerated curing not be pursued. The manufacturer is aware of this situation and is working to adjust the formulation to accommodate elevated-temperature curing where necessary.

Refer to Section 10 of Reference 5 for greater details.

6.3 SCALE-UP

There are no scale-up issues because the demonstrations used full-scale equipment.

6.4 OTHER SIGNIFICANT OBSERVATIONS

Painting and de-painting operations are a significant source of hazardous waste for the DoD.[6] The environmental impact results largely from the emission of heavy metal compounds and VOCs that are contained in primer and topcoat formulations, which are released during painting operations as HAPs. Despite an 80% reduction in VOC emissions over the four-year period from 1993-1997, the NADEPs typically discharge 60,000 pounds of VOCs per year from coatings operations. The costs related to hazardous waste have also risen dramatically - by more than 20% per year at one NADEP. Hard controls can cost up to \$1M/hangar and fines up to \$25K/day/facility. Downtime due to non-compliance would significantly affect force readiness. Army Research Laboratory documented the Army's hazardous waste generation from coating related operations to be even higher: 680 tons of painting wastes at 28 operation sites and a staggering 2,000 tons associated with de-painting at 16 locations. The Marine Corps estimation of VOC emissions from primers and topcoats was 80 tons. Air Force estimates indicate that painting operations cost over \$150M per year, and hazardous materials comprise a significant percentage of that amount.[5] Hazardous ingredients in primer and coatings formulations must be reduced to meet new environmental regulations and protect worker safety.

6.5 LESSONS LEARNED

The planning of demonstrations at military/contractor rework facilities is difficult due to several factors. Issues such as workload, weather, asset availability, and personnel changes can affect the timetables for painting and deployment. The following suggestions are given for those who pursue new coating demonstrations. First, arrange for demonstrations on assets that will give you the widest variety of platforms. This way, the new technology will experience the most possible operating environments. Next, arrange for demonstrations at multiple locations. Not only will this help with the first suggestion, but it will also provide for alternatives should one site not have any available assets or an unusually heavy workload. Lastly, have as many persons available to assist the principal investigator and site point of contact when the demonstration finally is performed. One extra day of preparation, artisan training, and final instructions can make the difference between a successful demonstration and validation of a promising new technology and an uphill battle to repair poor performance perception.

6.6 END-USER/ORIGINAL EQUIPMENT MANUFACTURER (OEM) ISSUES

The use of a zero-VOC topcoat is expected to have several benefits that will be applicable to any DoD facility or subcontractor engaged in the painting of aircraft or support equipment. Some of the regulatory, economic, and readiness benefits will include the following:

- Avoidance of fines (up to $25K/day/facility)
- Avoidance of hard emission controls (up to $1M/hangar)
- Reduced waste and disposal costs (more than 15,000 lbs. of solvent/NADEP)
- Improved work space/facility environment

Decreased downtime because of compliance means improved operational readiness.

The end users for this technology will be all DoD weapons systems that incorporate MIL-PRF-85285 polyurethane topcoat in their finishing system. Because the technology is a replacement for MIL-PRF-85285, the majority of the testing is based on this specification. Successful laboratory testing followed by favorable field demonstrations (addressed in the Reference 2, Section 3.26) will allow for transition of this technology to the user community. JTP endorsements were received from NAVAIR 4.3.4 (Aerospace Materials Division), all NADEPs, and the following Air Force program offices: Corrosion Program Office, C-130, C-141, C-5, Vehicles, F-15, and helicopters.

After successful completion, the transition of technology will be accomplished through technical manual revisions, specification revisions (MIL-PRF-85285C), and aircraft finishing specification (e.g. MIL-STD-7179) modifications through Integrated Product Teams (IPT) and the Acquisition Environmental Product Support Team (AEPST). MIL-PRF-85285 has been modified to incorporate a new Class W for waterborne coatings and a Type III for systems having 50 g/L VOC and less. Additional changes will be promulgated through the services' corrosion control manuals (NAVAIR 01-1A-509, T.O. 1-1-691, TM 1-1500-344-23) and to the Air Force's paint application manual T.O. 1-1-8.

Potential transition to the Original Equipment Manufacturer (OEM) community has been identified. Sikorsky Aircraft contacted NAWCAD in April 1998 for information regarding the proposed demonstrations under the ESTCP project. Sikorsky Aerospace coated an H-60 helicopter with the zero-VOC topcoat on 14 November 2000. Also, Hamilton Standard developed specification HS 7136 Rev F for use of this technology on aircraft propeller blades.

Refer to Section 9.2 of Reference 5 for more details.

6.7 APPROACH TO REGULATORY COMPLIANCE AND ACCEPTANCE

Federal, state and local environmental agencies like the Environmental Protection Agency (EPA) and California Air Quality Management Districts (AQMD) classify many VOCs as hazardous and restrict their emissions through regulations such as the Clean Air Act, Clean Water Act, Resource Conservation and Recovery Act (RCRA) as well as local EPA and AQMD rules. Also, Commander of Naval Operations (CNO) directives require significant reductions in the amount of hazardous waste generated by the Navy.

The EPA has proposed a reduction in low-level ozone non-attainment levels within the National Ambient Air Quality Standards (NAAQS). Because VOCs from topcoats contribute to the generation of low-level ozone, state and local agencies may require VOC reductions beyond those listed in the aerospace National Emission Standards for Hazardous Air Pollutants (NESHAPs).

Numerous federal and state environmental regulations apply to paints and coatings. The largest drivers are Executive Orders 12586 and 13148. Enacted by President Clinton in August 1993, Executive Order 12586 requires DoD activities to reduce the transport of hazardous materials from their activity by 50% by 1999. Enacted in April 2000, Executive Order 13148 requires "Greening the Government" by additional 40-50% reductions in toxic/hazardous chemical use and emissions by the end of 2006. Also, the California SCAQMD and California air resources Board (CARB) rulings have eliminated the utilization of chromium in manufacturing/industry. Follow-on rulings are anticipated to be even more stringent than those previously enacted. Use of a zero-VOC topcoat goes beyond compliance with these and future regulations because the material is non-toxic and generates no hazardous emissions and/or waste.

7.0 REFERENCES

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4. *Zero-VOC Waterborne Polyurethane Topcoat*, Technology Demonstration Plan developed under ESTCP Project Number 199802, dated 16 November 2000.

5. Demonstration/Validation of a Zero-VOC Waterborne Polyurethane Topcoat, Final Report developed under ESTCP Project Number 199802, dated 4 February 2002.

6. Col. K Cornelius, “DoD Hazardous Waste Minimization Efforts,” Presentation at the Fifth Aerospace Hazardous Waste Minimization Conference, Costa Mesa, CA, May 1990.

APPENDIX A

POINTS OF CONTACT

Point of Contact (Name)	Organization (Name & Address)	Phone/Fax/E-mail	Role in Project
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APPENDIX B

TECHNOLOGY ASSUMPTIONS

Parameter	Value	Data Source	
Surface area covered by solvent paint (ft^2/gal)	359	Powdercoat Assn	calculation derived from estimated mil thickness, paint transfer efficiency, % paint solids
Coating thickness (ml)	1	reported thickness	
Conventional paint % solids	56		
Spray painting transfer efficiency (%)	40		
Surface area covered by zero VOC paint (ft^2/gal)	359	Powdercoat Assn	calculation derived from estimated mil thickness, paint transfer efficiency, % paint solids
Unit cost of solvent paint ($/gal)	$66.14	NADEP Jax data	
Unit cost of zero VOC paint ($/gal)	$70.40	Deft Inc.	
Unit cost of thinner ($/gal)	$8.13	NADEP Jax data	
solvent painting labor hours (hr/ft^2)	0.0164	estimate	
zero VOC Labor Hours (hr/ft^2) (equal to solvent)	0.0164	Eng. Estimate	
solvent paint density (lb/gal)	10.43	Mil-C-85285 MSDS	
Density of zero VOC paint (lbs/gal)	10.30	Deft Inc.	
Thinner density (lb/gal)	6.81	Mil-T-81772	
% of spray paint by weight as hazardous waste	80.00%	NADEP Jax data	
% zero VOC paint as hazardous waste	25.00%	Deft Inc.	
% thinner as hazardous waste	85.00%	Eng. Estimate	
% paint volume as thinner needed for solvent cleanup	25.00%	NADEP Jax data	
% paint volume as thinner needed for zero VOC cleanup	5.00%	Eng. Estimate	
Wastewater generated from zero VOC, as percent paint	15.00%	Tech Library Estimate	
Wastewater treatment cost ($/gal)	1	NADEP Jax	
VOC Equipment Control Cost ($/booth)	$25,000	NADEP Jax data	based on an estimated equipment cost of $75,000 for 3 booths at Jax
VOC Equipment Annual PM Costs ($/booth)	$8,333	NADEP Jax data	based on an estimated PM cost of $25,000 for 3 booths at Jax
Permit/reporting ($/booth)	2000	NADEP Jax & NADEP Cherry Pt data	
VOC blower operating hours (12 hr/day)	3000	assumption	
Operating Days	250	assumption	
VOC blower energy (5.6 kw)	16,800.00		
VOC blower energy cost ($/booth)	300		

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