ARMY RESEARCH LABORATORY

# Paint Survey of Patriot Vehicles

**by Pauline Smith and Kestutis Chesonis**

**ARL-TR-3909** **September 2006**

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**Pauline Smith and Kestutis Chesonis**
**Weapons and Materials Research Directorate, ARL**

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**14. ABSTRACT**

The U.S. Army Research Laboratory has evaluated new water-reducible wash primers that do not contain hexavalent chromates and significantly minimize volatile organic compound (VOC)- and hazardous air pollutant-potential emissions during coating operations. The new wash primers are water-borne acrylic latex emulsions with corrosion-inhibiting pigments. The three water-reducible acrylic latex emulsion formulations are designed for use under MIL-P-53030, a water-reducible lead and chromate-free epoxy primer. Tests are required on military equipment to validate the completed laboratory and controlled testing. The ultimate objective of the process is to demonstrate that the low VOC wash primers can provide a "drop-in" solution to the environmental issues associated with the solvent-based primer currently in use and provide equal or better performance involving no significant changes to the application and stripping procedures currently being used.

The field demonstration of this coating was tested on a Patriot truck unit, with serial no. 630106, at the Letterkenny Army Depot facility, Chambersburg, PA. The unit is an engagement control system (ECS). The ECS is the only manned station in the battery during the air battle and is the operations control center of the Patriot battery. The ECS contains the weapons control computer, man/machine interface, and various data and communication terminals. Its prime mover is a 5-ton tactical cargo truck.

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## 1. Introduction

On the 24th and 25th of January 2006, a paint survey of Patriot vehicles was conducted at the Lower Tier Project Office, Fort Bliss facility located in El Paso, TX. The survey's intent was to inspect paint delamination at the seam line on an engagement control system (ECS), further document any paint defects on the other Patriot vehicles, and provide recommendations on materials and procedures to prevent, repair, and control the observed damage. The coating system on the ECS was the water-reducible wash primer Kem Aqua supplied by Sherwin-Williams; epoxy primer was MIL-DTL-53030 supplied by DEFT; and the topcoat was MIL-DTL-53039A supplied by Hentzen.

## 2. Survey Procedures

The survey of the Patriot vehicles occurred through visual inspection. Whenever possible, paint survey team (PST) members canvassed the attached Patriot and military personnel for additional observations of adhesion defects. The additional comments were then recorded and documented. Analytical equipment was used during the vehicle inspections to measure film thickness of coated areas adjacent to the delaminated, bare metal seam areas. Detailed descriptions of any paint defects were entered by PST members, and photographs were taken of the corresponding damage areas. Representative paint chips were removed for laboratory analysis at the U.S. Army Research Laboratory (ARL) and Aerospace Materials Function/Missile U.S. Army Research, Development and Engineering Center (RDEC).

The Aerospace Materials Function/Missile RDEC analyzed the paint and polyester filler chips that were removed from the trial Patriot ECS unit. A cross section of both chips was prepared metallographically for inspection using a metallograph.

The micrographs presented in figures 1–2 depict the coating layers present on the paint chip. The top two layers appear to be black and green chemical agent resistant coating topcoat. The third layer down appears to be a white primer, and the bottom layer appears to be the water-reducible wash primer (Sherwin Williams' Kem Aqua). No polyester filler was detectable on the chip, as noted by RDEC. In figure 1, each division of the ruler is equivalent to 0.0004 in. The average thickness of the water-reducible wash primer remaining on the chip is ~0.001 in.

Figure 3 is a micrograph of the polyester filler. It does not appear that any of the polyester filler material shown in figure 3 is present underneath the wash primer layer on the paint chip. The absence of any polyester filler on the paint chip indicates a lack of adhesion between the water-reducible wash primer and the polyester filler material.

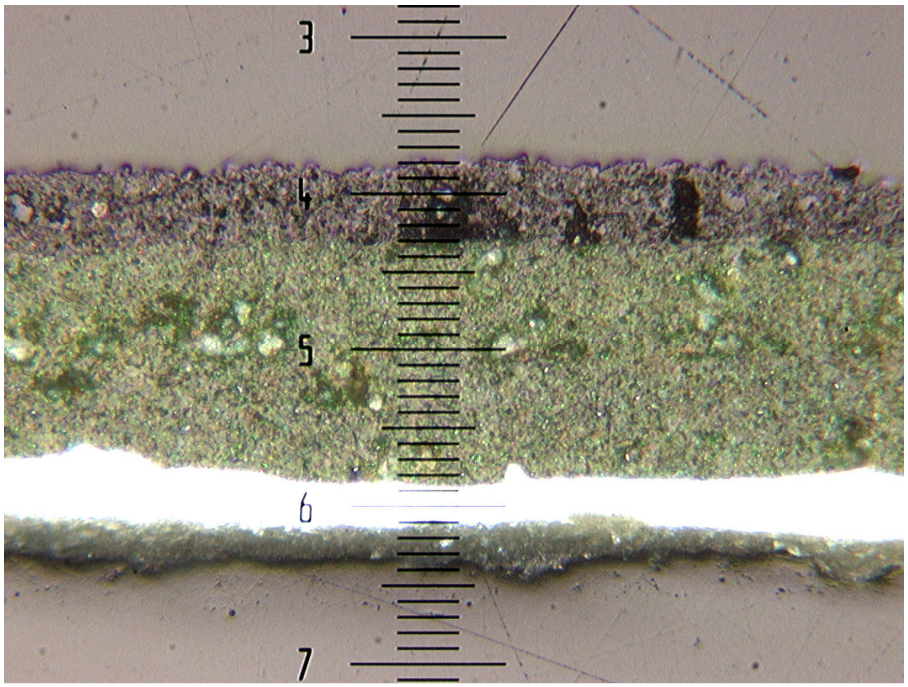


Figure 1. Micrograph of paint chip removed from Patriot ECS shelter with water-reducible wash primer; 1 div = 0.004 in.

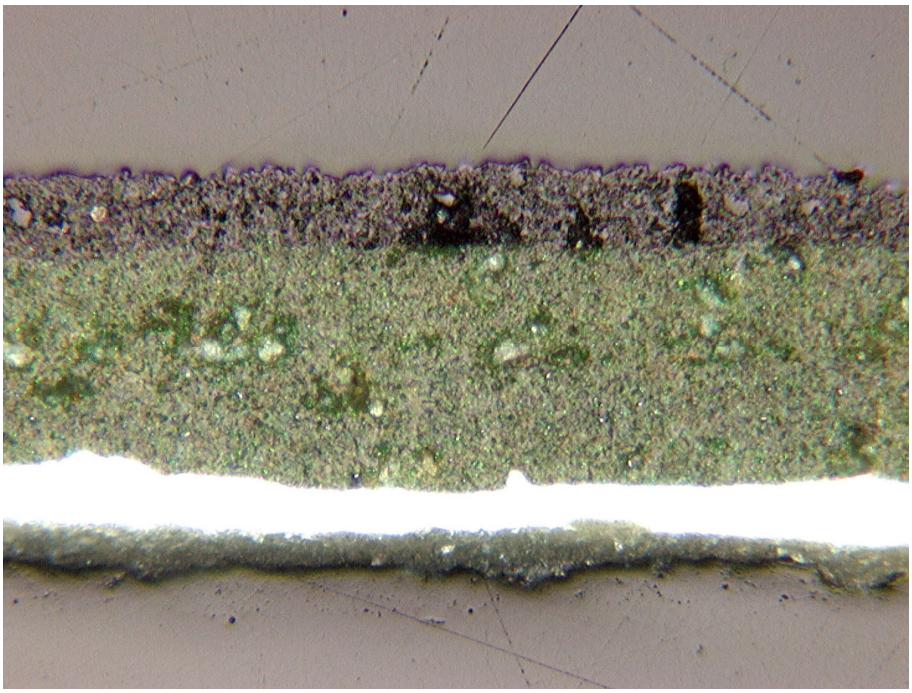

Figure 2. Micrograph of paint chip removed from Patriot ECS shelter with water-reducible wash primer.

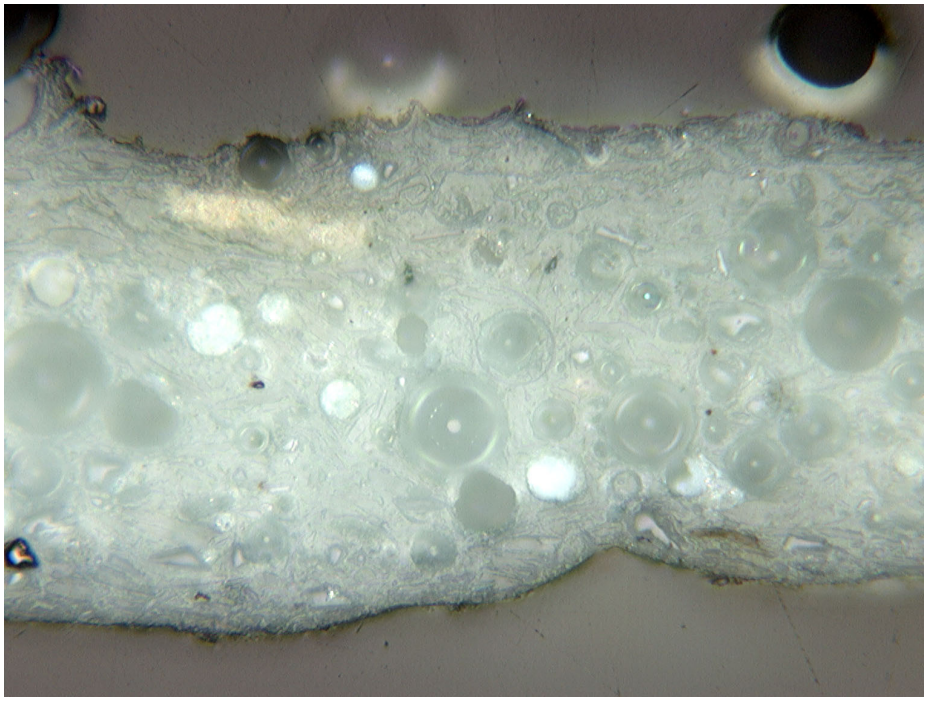

Figure 3. Micrograph of polyester filler removed from the Patriot ECS shelter with water-reducible wash primer.

ARL analyzed samples of the paint chips using metallographic cross sections of the coating samples prepared in Bakelite. The coating system was cleanly fractured, mounted perpendicular to the fractured edge, and mechanically ground and polished through 0.02-µm colloidal silica. The mounted cross sections were then examined on a Nikon Epiphot 300 inverted metallograph. Digital micrographs were acquired of the coating system. The individual coating system layers were counted, and their respective thicknesses were measured. Figures 4–6 present the coating system cross-sectional photomicrographs. The coating system can be observed within the mounting media comprising the material at the top and bottom of the figures.

The results of this analysis indicate an adhesive failure between the water-reducible wash primer and the polyester filler. Possible causes include material incompatibility between the water-reducible wash primer and the polyester filler or contaminants on the surface of the polyester filler prior to application of the water-reducible wash primer. The paint chip from the new wash primer showed four layers of coating, while the control sample showed three coatings.

This survey primarily focused on adhesion and paint damage resulting from daily routine operation and use of Patriot vehicles in outdoor locations.

Table 1 lists the Patriot vehicles inspected by the PST.

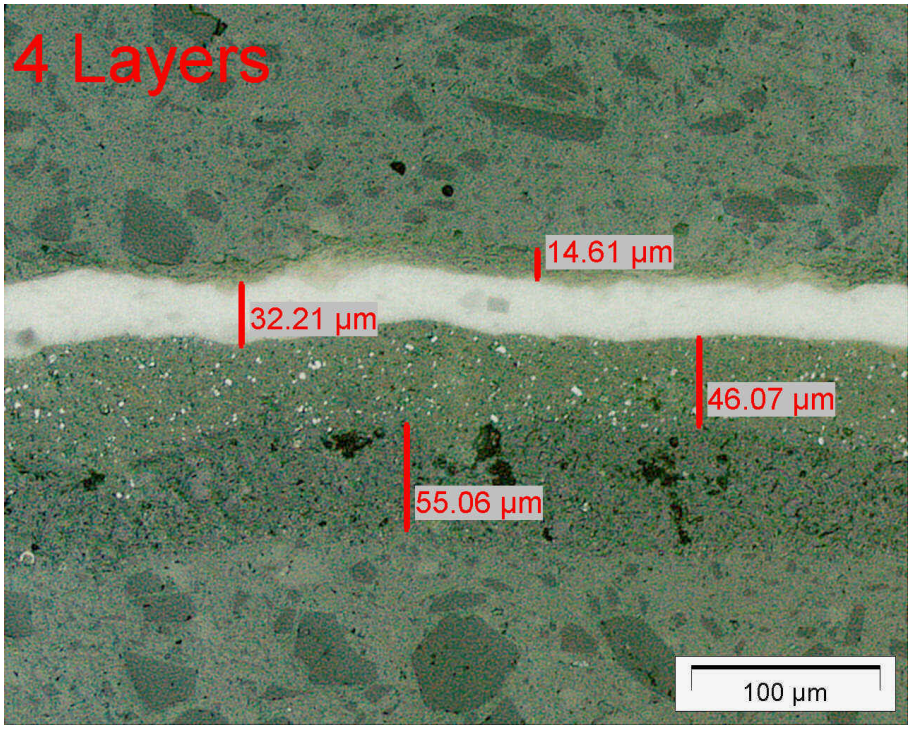


Figure 4. Micrograph of paint chip removed from Patriot ECS shelter with water-reducible wash primer.

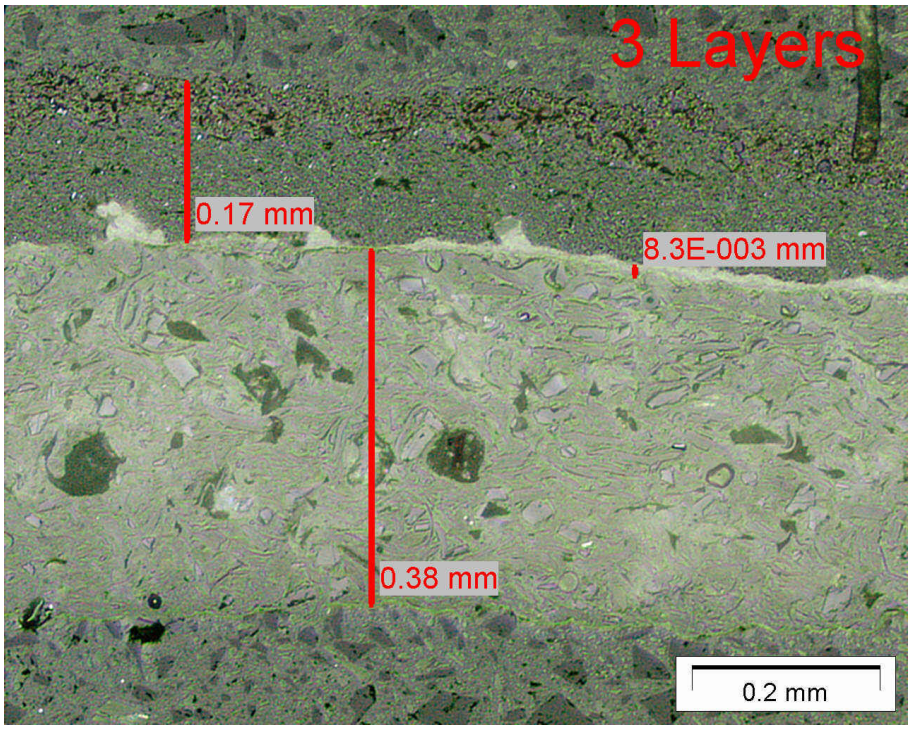


Figure 5. Micrograph of paint chip removed from Patriot communications relay group (CRG) shelter with control wash primer.

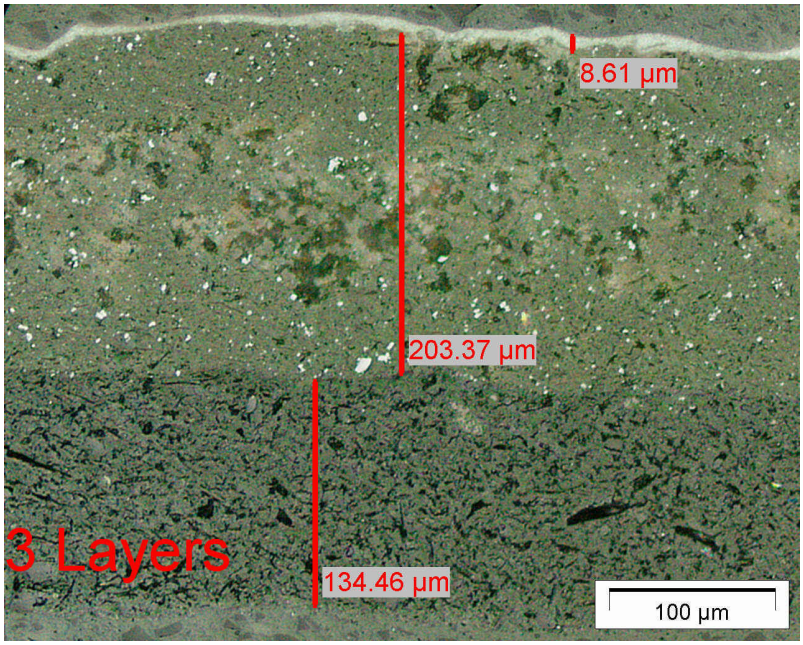


Figure 6. Micrograph of paint chip removed from Patriot ECS shelter with control wash primer.

Table 1. Vehicle exterior inspections.

| Serial No. | Unit Type | Overhaul Date | Color | Wash Primer | Comments |
|---|---|---|---|---|---|
| 720007 | ECS | Oct. 05 | Green w/camo | DOD-P-15328 | No paint system failures noted. |
| 700117 | ECS | NP[a] | Green w/camo | DOD-P-15328 | No paint system failures noted. |
| 630106 | ECS | June 06 | Green w/camo | Low VOC WP | Two failures; multiple cracking along butt seam joints on two sides. |
| 810003 | ECS | June 03 | Desert tan | DOD-P-15328 | No paint system failures noted. |
| 620453 | SRPT | Sep. 05 | Green w/camo | DOD-P-15328 | No paint system failures noted. |
| 620456 | ECS | Feb. 05 | Green w/camo | DOD-P-15328 | Paint cracking on sealer only (lap joint). |
| 680516 | CRG | Aug. 05 | Green w/camo | DOD-P-15328 | No paint system failures noted. |
| 620454 | CRG | May 05 | Green w/camo | DOD-P-15328 | One failure; multiple cracking along butt seam (paint not adhering at this seam). |
| 660115 | CRG | Oct. 05 | Green w/camo | DOD-P-15328 | No paint system failures noted. |
| 700251 | CRG | Jan. 05 | Green w/camo | DOD-P-15328 | No paint system failures noted. |
| 680007 | CRG | July 05 | Green w/camo | DOD-P-15328 | No paint system failures noted. |
| 640251 | SRPT | NP[a] | Green w/camo | DOD-P-15328 | No paint system failures noted. |
| 690204 | SRPT | NP[a] | Green w/camo | DOD-P-15328 | No paint system failures noted. |
| 660110 | SRPT | NP[a] | Green w/camo | DOD-P-15328 | No paint system failures noted. |
| 810166 | ECS | Oct. 04 | Green w/camo | DOD-P-15328 | Paint cracked, separated from metal on antenna mast plate. Looks like plate was not prepped with wash primer. |
| 780335 | ECS | Dec. 01 | Green w/camo | DOD-P-15328 | Front bumper some peeling of nonskid paint; otherwise no paint failures on shelter. |
| 600077 | ECS | June 99 | Green w/camo | DOD-P-15328 | Twelve places spread on shelter where paint has cracked or peeled. |

[a]NP = not provided.
Note: SRPT = small repair parts transporter, and CRG = communications relay group.

Additional comments on the survey and its results are listed next.

1. ECS, serial no. 720007, overhaul date 10/05 (figure 7). No paint failure was noted, and the overall impression of the vehicles was very good.


Figure 7. ECS; serial no. 720007; overhaul date 10/05.

2. ECS, serial no. 630106, overhaul date 05/05 (figures 8–13). There were two areas of paint adhesion failure on the outside vertical seam where the paint (1/4 –1 in) had peeled away or delaminated. Film delamination occurred only at the seam and only where the polyester filler was applied. Rivet head outlines could be seen along the entire seams. Expansion and contraction forces along the butt seam may be a contributing factor. This failure appeared to be localized at the weakest interface along the butt seam (i.e., between primer and body filler or substrate and body filler). Mechanical forces causing flex of the substrate (evidenced by the rivet heads) distorted the coatings. The coatings then separated at the weakest interface that appeared to be the body filler – substrate interface. This Patriot ECS unit was painted using the low volatile organic compound (VOC) water-reducible wash primer at Letterkenny Army Depot, Chambersburg, PA, and fielded at Fort Bliss, TX. The two areas of concern were sections of the shelter where the walls were replaced. The walls were bonded using a polysulfide sealer and a polyester filler. The filler material appeared to have a heavy film. Dry film thickness measurements (1 mil = 0.001 in) were taken at four different areas, with data recorded in table 2. Due to high temperatures, the shelter walls expanded, causing the paint filler to crack and peel along the butt joints where replacement wall sections met older wall sections. A knife blade easily removed painted filler along the edges for laboratory analysis.


Figure 8. ECS right side; serial no. 630106; overhaul date 05/05.

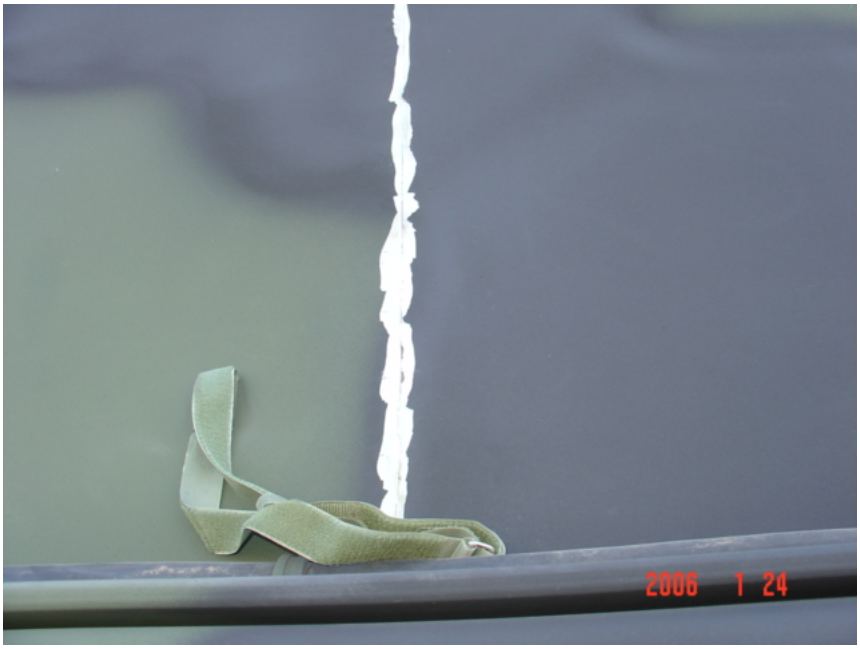


Figure 9. ECS left side; serial no. 630106; overhaul date 05/05.

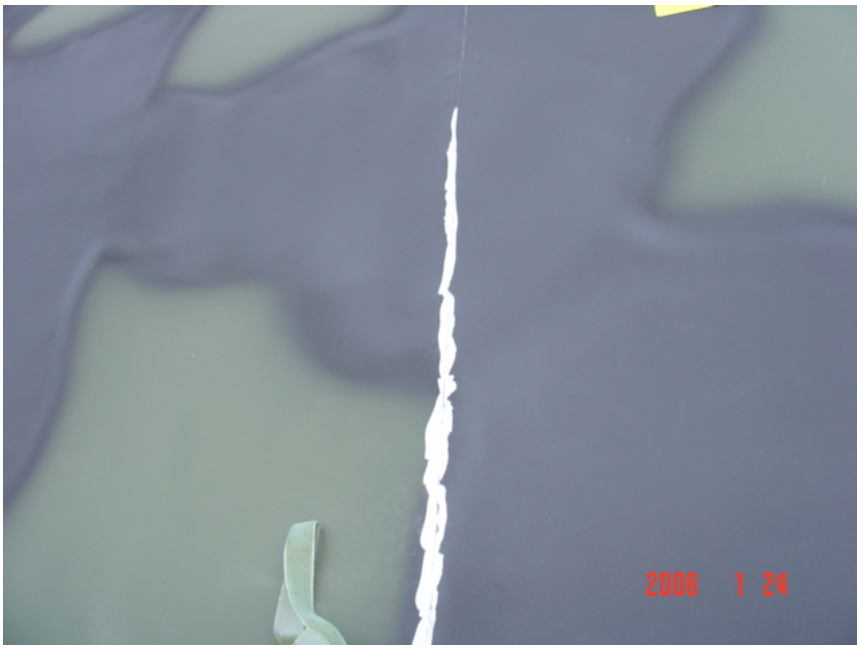


Figure 10. ECS after tape pulled off; serial no. 630106; overhaul date 05/05.

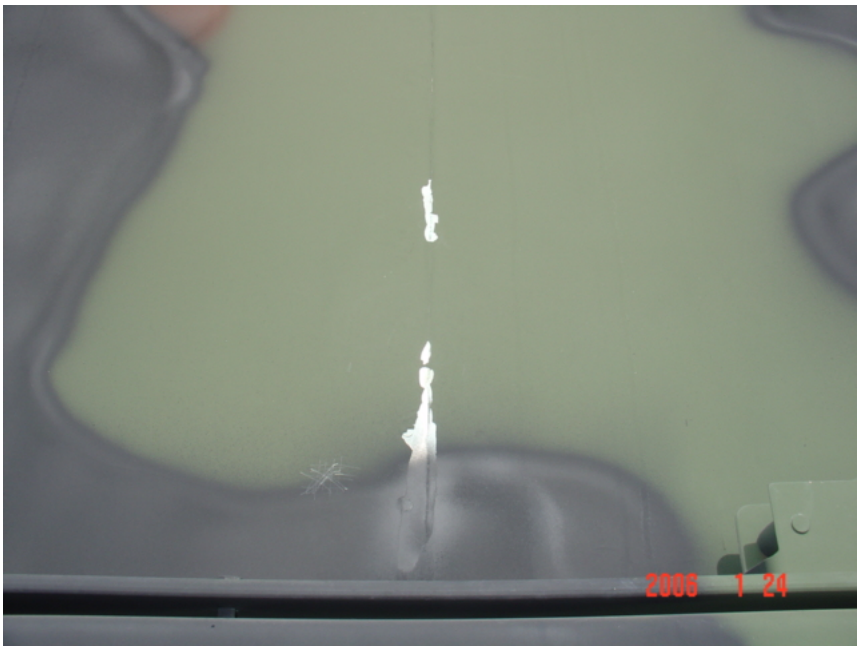


Figure 11. ECS before tape pulled off; serial no. 630106; overhaul date 05/05.

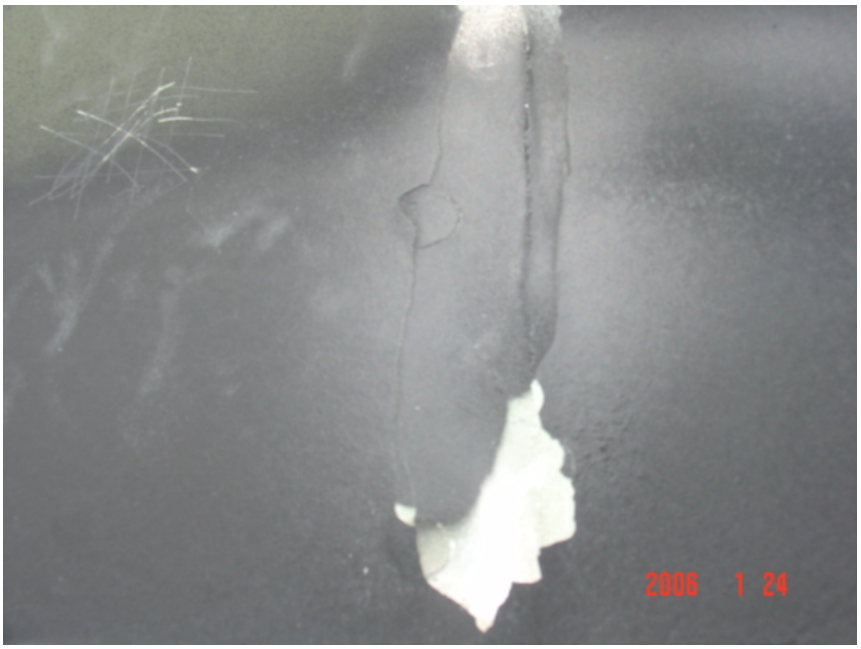


Figure 12. ECS area with bondo; serial no. 630106; overhaul date 05/05.

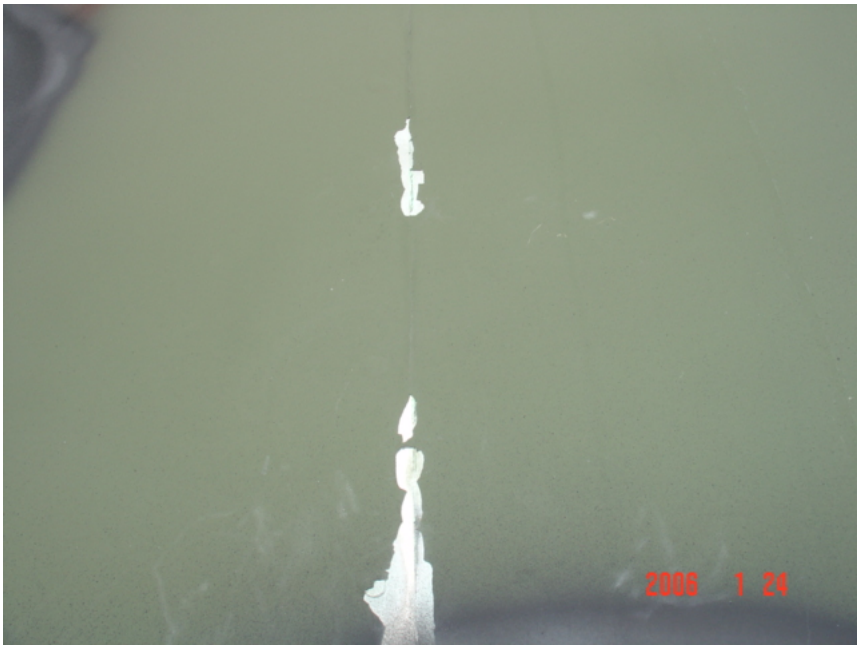


Figure 13. ECS before tape pulled off; serial no. 630106; overhaul date 05/05.

Table 2. Dry film thickness (1 mil = 0.001 in).

| Dry Film Thickness (mil) | | | |
|---|---|---|---|
| **Painted Area** | **Body Filler + Filler + Paint** | **Filler + Sealer** | **Painted Area** |
| 7.10 | 19.90 | 4.25 | 7.70 |
| 7.21 | 17.10 | 4.25 | 6.86 |
| 8.33 | 21.90 | 3.66 | 6.86 |
| 7.46 | 13.80 | 1.63 | 9.50 |

3. ECS, serial no. 700117, no overhaul date provided. No paint failure was noted, and the overall impression of the vehicle was good.

4. ESC, serial no. 810003, overhaul date 06/03 (figures 14–17). No paint failure was noted, and the overall impression of the vehicle was very good.


Figure 14. ESC rear images; serial no. 810003; overhaul date 06/03.


Figure 15. ESC full view; serial no. 810003; overhaul date 06/03.


Figure 16. ESC seam with cracks; serial no. 810003; overhaul date 06/03.


Figure 17. ESC; serial no. 810003; overhaul date 06/03.

5. SRPT, serial no. 620453, overhaul date 09/05. No paint failure was noted, and no filler material was used.
6. Raytheon. Paint failure was noted along sealed edges.
7. CRG, serial no. 620456, overhaul date 02/05 (figures 18–21). No paint failure was noted, and the overall impression of the vehicle was good.

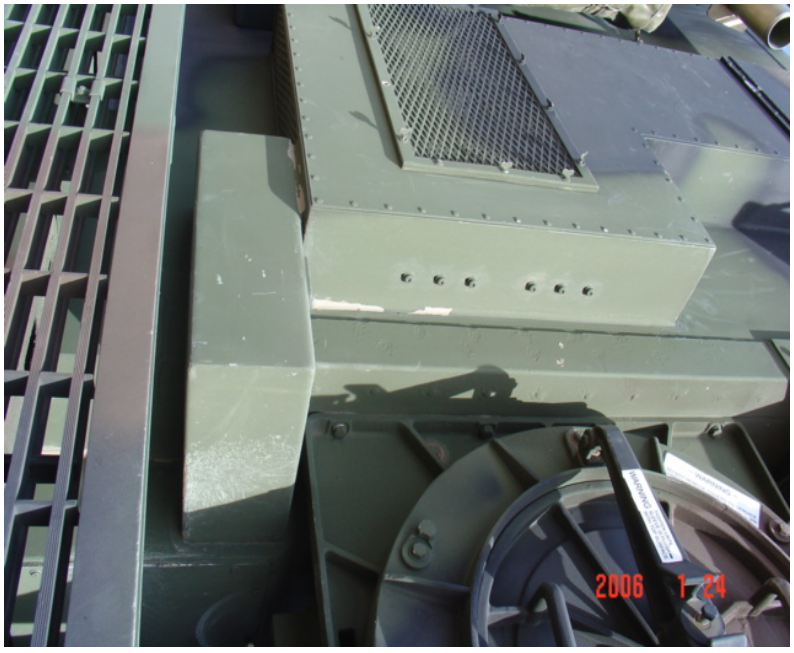


Figure 18. CRG; serial no. 620456; overhaul date 02/05.


Figure 19. CRG; serial no. 620456; overhaul date 02/05.


Figure 20. CRG left side; serial no. 620456; overhaul date 02/05.


Figure 21. CRG areas showing paint chip; serial no. 620456; overhaul date 02/05.

8. CRG, serial no. 680516, overhaul date 08/05. No paint failure was noted, and the overall impression of the vehicle was good.

9. CRG, serial no. 620456, overhaul date 05/05 (figures 22–26). There were areas of paint filler adhesion and damage to the exterior where the paint and filler (1/4–1 in) had peeled away or delaminated. Rivets appeared loose. The paint, filler material, and sealant along the seam were removed. A knife blade easily removed paint and filler along the edges for laboratory analysis. This vehicle was painted with the current paint system but exhibited paint failure along the butt seam joint similar to the low VOC wash primer trial unit.

10. CRG, serial no. 660115, overhaul date 10/05. No paint failure was noted, and the overall impression of the vehicle was very good.

11. CRG, serial no. 700251, overhaul date 01/05. No paint failure was noted, and the overall impression of the vehicle was good.

12. CRG, serial no. 680007, overhaul date 07/05. No paint failure was noted, and the overall impression of the vehicle was good.

13. SRPT, serial no. 640251, overhaul date not provided. No paint failure was noted, and the overall impression of the vehicle was good.

14. SRPT, serial no. 690204, overhaul date not provided. No paint failure was noted, and the overall impression of the vehicle was good.


Figure 22. CRG paint chip from a distance; serial no. 620456; overhaul date 05/05.


Figure 23. CRG paint being removed; serial no. 620456; overhaul date 05/05.

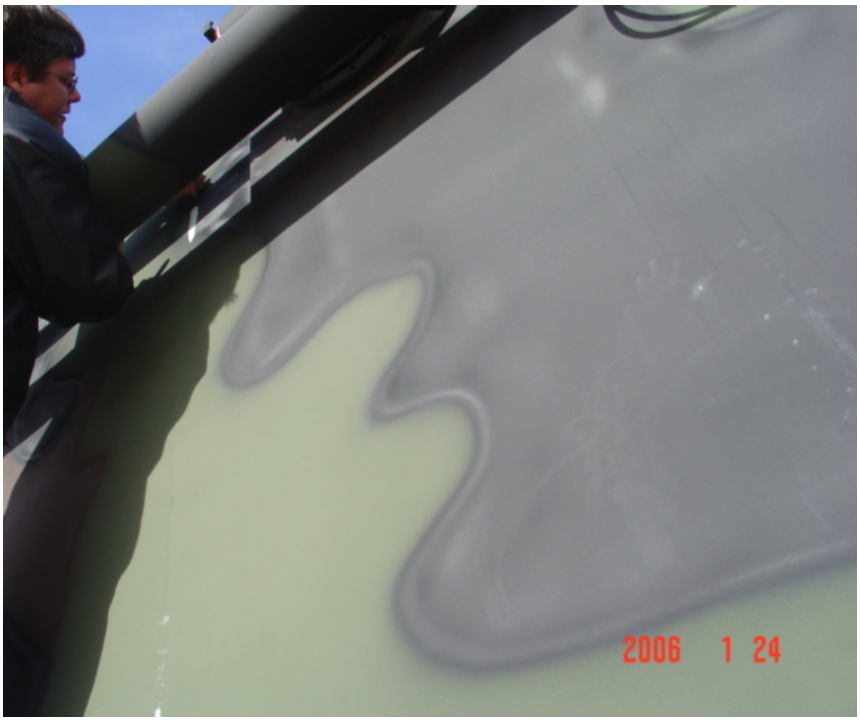


Figure 24. CRG delaminated area; serial no. 620456; overhaul date 05/05.

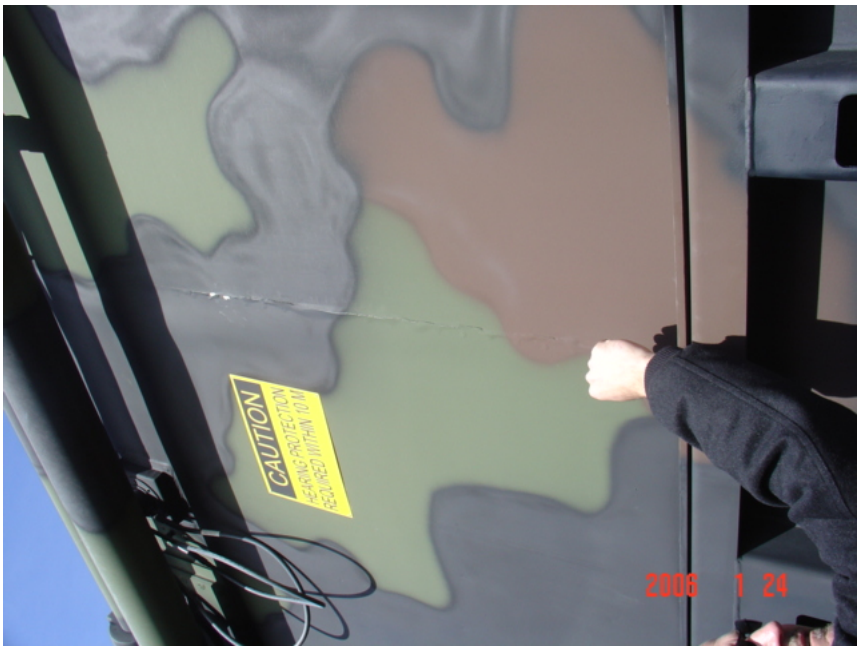


Figure 25. CRG delaminated paint area; serial no. 620456; overhaul date 05/05.

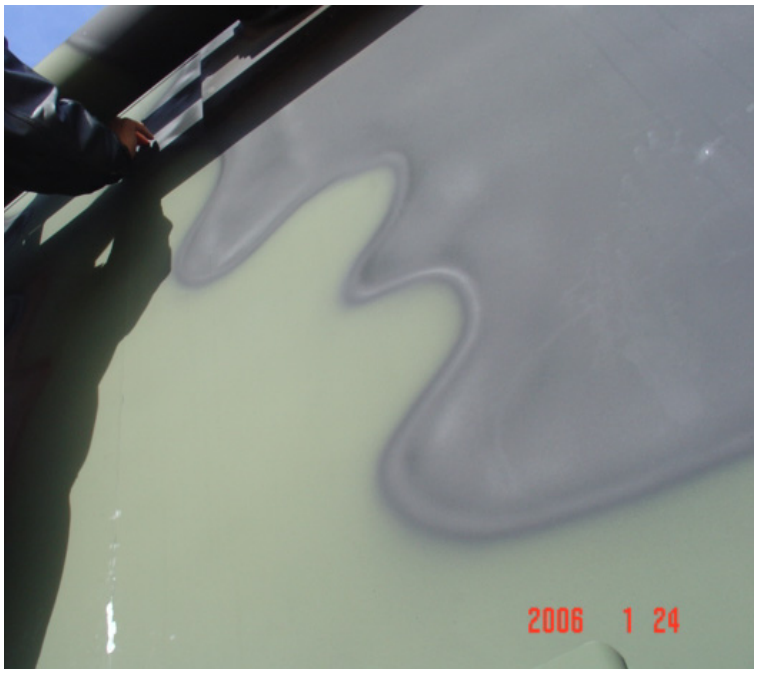


Figure 26. CRG delaminated paint being removed; serial no. 620456; overhaul date 05/05.

15. SRPT, serial no. 660110, overhaul date not provided. No paint failure was noted, and the overall impression of the vehicle was good.

16. ECS, serial no. 810166, overhaul date 10/04 (figures 27–30). No paint failure was noted on the shelter or vehicle; antenna mast attachment plate had cracked paint. Paint system completely separated from the substrate. Chip was removed for analysis. No visible evidence of wash primer appeared. Paint chip removal showed bare metal (aluminum).


Figure 27. ECS paint failure; serial no. 810166; overhaul date 10/04.


Figure 28. ECS antennae mast attachment; serial no. 810166; overhaul date 10/04.


Figure 29. ECS antennae showing paint delamination; serial no. 810166.


Figure 30. ECS multiple layers of paint; serial no. 810166.

17. ECS, serial no. 780335, overhaul date 10/01. Front bumper on truck had peeling of nonskid paint; otherwise, no paint failures were noted on the shelter.

18. ECS, serial no. 600077, overhaul date 06/99 (figure 31). Twelve noted areas of paint defects were noted where paint had either cracked or peeled.


Figure 31. ECS paint delamination; serial no. 600077; overhaul date 06/99.

## 3. Observations

1. Fort Bliss uses Rexcels'Aqua Strip solvent, a hazardous air pollutants (HAPs)-free, water-soluble solvent for paint thinning and cleaning purposes, instead of MIL-T-81772.
2. For RECAP (RECAPITALIZATION), individual metal parts are sandblasted. Plastic media is used on aluminum and grit no. 50 for steel.
3. Fort Bliss specializes in RECAP of the Patriot launchers (figures 32–34). There was one instance where the launcher bed was heavily corroded. The area was exposed, water had settled, and there was no drainage.


Figure 32. Launcher bed.


Figure 33. Launcher cabinets.


Figure 34. Launcher.

4. Fort Bliss utilizes wash primer on all equipment. A temporary red oxide primer is used between sand blasting and painting to prevent corrosion.
5. The current wash primer formulation contains 7.1% by weight of zinc chromate and has 6.5 lb/gal of VOC that are classified as HAPs. Upon paint removal or stripping, the chromate wash primer, which contains t hexavalent chromium, contaminates all paint waste. This paint waste must be disposed as a chromium-containing hazardous waste. However, solid paint waste at Fort Bliss is not regulated.

## 4. Summary and Recommendations

- MIL-DTL-53072[1] does not address the use of any filler material with the CARC coating systems. The original intent was to evaluate the new wash primer over the aluminum bodied ECS. "Bondo" and fillers were not in our coating systems.
- In the automotive refinishing field, the polyester/peroxide filler type is the most common due to low cost and a fast curing rate. The major drawback is the substantial shrinkage that occurs with curing. Better performing fillers without shrinkage are the two-component epoxy; however, the disadvantages are higher cost and much longer cure time before it can be sanded (the main objection).
- The legacy wash primer uses a vinyl butyral resin known for its adhesion to metal and glass and is admixed with phosphoric acid (3.67% of formula) prior to use. The new wash primers use an emulsion polymer and contain no free acids.

[1]MIL-DTL-53072. *CARC System Application Procedures and Quality Control Inspection* **2003**.

- Bondo Corp. manufactures various grades of polyester fillers. In communications, the word “bondo” has become generic; the real filler used for this operation was made by Everseal.
- The butt seam repair process is where a damaged section of wall is cut out. A new wall section is cut to size, pretreated, glued into place, riveted down, rivets are ground smooth, body filler is applied over the seam, and the body filler is then sanded smooth and feathered down on the edges to make the wall section smooth in appearance.
- It appears that the construction method where a damaged wall section is cut out and replaced using a butt seam is a potential weak link where expansion and contraction can cause cracking or peeling at the weakest place.
- No failures were noted on SRPT trailers. One major difference is they don’t use the butt seam construction method. They utilize lap seams, the rivets are not ground down, and no body filler is used; however, a seam sealant is applied to seal the lap seam.
- This travel mission showed that the butt seam process on ECS and CRG shelters is a cause for concern with both paint systems (either the current acid wash pretreatment or the new low VOC wash primer). One unit with a similar defect to the trial unit was found using the paint system with the current wash primer.
- If aesthetics is insisted for the seam line, ARL would suggest using epoxy fillers with a proven record. Additional test/evaluation with various water immersions at room and higher temperatures would be required and evaluated for 6 months by EMMAQUA.
- In conclusion, an evaluation of the lap seam vs. the butt seam construction method should take place. It is too early to say definitively that the lap seam method will cure seam cracking, but early evidence may offer a possible solution. A test utilizing a lap seam construction on an ECS or CRG is recommended. It should be noted that out of all shelters, only two exhibited the butt seam cracking failure. Additional testing of the low VOC wash primer on full-size shelters would also assist in the overall data assessment. If additional testing is performed, some units with both the lap seam construction and the butt seam construction should be painted with the low VOC, water reducible wash primer.

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