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Corrosion Surveys of Army Ground Assets to Identify Leading Issues and
Opportunities for Corrosion Prevention

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ABSTRACT

Army Regulation (AR) 750-59 requires the Corrosion Prevention and Control (CPC) program manager to conduct a survey of Army Materiel for corrosion on a 4-year basis. With Army ground assets estimated to number at over 500,000, statistical sampling of equipment and installations was determined to be the most effective means to meet this requirement. Starting in FY2015, the Integrated Logistics Support Center (ILSC) at the Tank-Automotive and Armaments Command (TACOM), working with Tank Automotive Research, Development, and Engineering Center (TARDEC), contracted Elzly Technology Corporation (Elzly) to develop a methodology to perform these surveys and catalog the assessment data. From January 2015 through May 2018, Elzly and ILSC personnel have visited 22 installations, inspected over 8,200 assets, recorded corrosion or coating damage on over 121,000 parts, and have cataloged over 180,000 photos of parts with corrosion and coating damage (surveys continue today). As part of the methodology, Elzly developed customized database tools on a mobile platform to collect, organize and analyze the inspection data without needing to move or operate the equipment. The data collected is used to identify trends in corrosion observations, highlight parts that are common for all assets, or identify issues that are specific to vehicle platforms, certain models, or in certain areas. This information is used to inform Product Managers (PdMs) of corrosion prevention and control opportunities that exist, where military or commercially available technologies can be used to reduce this degradation. The information is also available to inform future acquisition programs on material, coating, or construction methods that can be used, reduce corrosion using design and manufacturing. This paper will provide an overview of the survey tool that had been developed for assessment of vehicles, a high-level summary of the data collected, and examples of reporting provided to facilitate corrosion prevention on ground assets, both currently fielded and being developed as part of a new acquisition program.

INTRODUCTION

Army Regulation (AR) 750-59 requires the Corrosion Prevention and Control (CPC) program manager to conduct a survey of Army Materiel for corrosion on a 4-year basis.[1] With Army ground assets estimated to number at over 500,000, statistical sampling of equipment and installations was determined to be the most effective means to meet this requirement. Starting in FY2015, the Integrated Logistics Support Center (ILSC) at the Tank-Automotive and Armaments Command (TACOM), working with TARDEC, contracted Elzly Technology Corporation (Elzly) to develop a methodology to perform these surveys and catalog the assessment data. From January 2015 through May 2018, Elzly and ILSC personnel have visited 18 installations, inspected over 8,200 assets, recorded corrosion or coating damage on over 121,000 parts, and have cataloged over 180,000 photos of parts with corrosion and coating damage.

Key to the collection of this data, was the ability to easily capture, store, analyze, and report on corrosion observations by installation, asset type, or specific assets where maintenance is needed. Collection of the data is enabled using iPads™ and custom software developed for capturing vehicle identification information, corrosion data, and pictures associated with each survey. Capturing data electronically at the point of inspection has eliminated the need for transcribing hand-written records, has allowed automating several data analysis methods for rapid reporting, and ensures photos taken are directly associated with the intended part, asset, and installation. Where more detailed engineering analysis is needed, this can easily be accomplished by exporting complete or consolidated data sets.

As part of these efforts, several reports are issued to each installation, ILSC/TARDEC, Program Managers (PMs), and Army Materiel Command (AMC). This starts with an out-brief, which is

provided on site at the completion of each week-long survey. This summarizes the data collected, identifies assets with the greatest observations of corrosion, and recommends general maintenance activities that could aid in reducing corrosion. Accompanying each out-brief is an Excel-based dashboard that provides the units the ability to identify assets where specific types of corrosion-related maintenance is recommended.

Within 45 days of each survey, a more detailed report is submitted to ILSC/TARDEC and the installation. This report identifies corrosion trends for parts, summarizes corrosion observations on assets identified by units as having corrosion issues, and provides engineering and maintenance opportunities for reducing corrosion. It also includes a comparison of corrosion severity of that installation relative to all previously surveyed locations.

At the end of each fiscal year (FY), a comprehensive report is provided to ILSC and TARDEC. This report summarizes specific activities performed over the past year, identifies trends in part corrosion observations at all installations, and maps the observed corrosion to opportunities for improvement. The opportunities within this report includes proposed fixes to reduce the observed corrosion, highlighting past research showing the performance of these technologies, and paths for their implementation. The Excel-based dashboard, which allows ILSC and TARDEC (or others) to query the data to identify specific corrosion issues, is also provided.

Starting in FY2017, TARDEC has begun to utilize the data collected during these corrosion surveys to facilitate discussions with Program Executive Offices (PEOs), PMs, and Product Managers (PdMs). Using the survey data, several briefs have been created that highlight observations of corrosion made on asset families. These briefs highlight parts where the most

corrosion has been observed geographically as well as parts with the most severe corrosion. Engineering changes and/or maintenance activities were included for each of the identified parts/issues. As surveys continue, TARDEC plans to expand the briefs provided to include all platforms currently managed by TACOM.

This paper will provide an overview of the survey tool that had been developed for assessment of vehicles, a high-level summary of the data collected through December 2017, and examples of reporting provided to facilitate corrosion prevention on ground assets, both currently fielded and being developed as part of a new acquisition program.

ASSESSMENT METHODOLOGY

Inspection of assets for corrosion sought to capture identifying information for grouping similar assets, identifying asset age, usage, location, as so forth. Collection of corrosion data sought to identify specific parts where degradation may occur, but also realized that there were certain items where cataloging the condition of individual parts (e.g., fasteners) would be impractical. It was also desired to relate corrosion data to the information being collected by the Corrosion Service Teams (CSTs); which perform a general corrosion assessment while performing corrosion prevention maintenance on assets. Finally, as part of these inspections, photo documentation was key and there was a desire to tag photos to the part, asset, area, and installation where the inspection was made (all electronic data is stored on password protected and encrypted devices). The inspections are performed by visually assessing the vehicle's condition without requiring soldiers to move, operate, or otherwise detract from their normal activities. Only access to all areas of the asset (including the interior) was needed.

Asset Identification

Identifying information is collected primarily using the data plate where information such as the National Stock Number (NSN), serial number, USA Number, and Date of Manufacture (DoM) is located. These or other data tags will also indicate if an asset has been rebuilt, typically listing the location and the date of rebuild. Other information collected include the bumper number (for tracking by the owning unit) and mileage/operating hours (only collected from analog gages).

Corrosion Data

Corrosion data is collected to identify the severity of the corrosion (stage), the type of corrosion, and the general condition of the coatings applied to the part/area. The severity of corrosion is rated based on the criteria in TB 43-0213, WP 0006 00, Inspection. This scale ranges from 0 through 4, with 0 being no corrosion and 4 being metal loss including perforation (Figure 1).

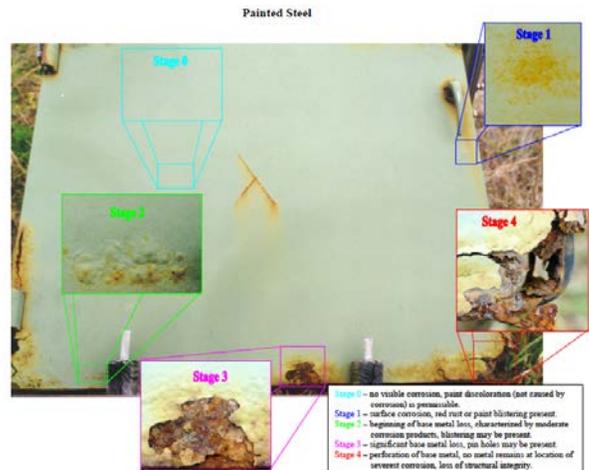


Figure 1. Example of Stages of Corrosion on Steel

During the assessment the type of corrosion observed is characterized as one of the following:

- General – corrosion that occurs randomly across the affected part/area
- Crevice – corrosion that occurs within a tight joint

- Pitting – localized corrosion that occurs at small areas, commonly observed on stainless steel
- Galvanic – corrosion occurring between two different metals in contact with each other

Lastly, the affected area is noted for presence of coating degradation/damage. This includes:

- Mechanical Damage – coating is damaged or degraded due to an outside event
 - Includes subcategories of Chipping, Abrasion, Wear, and Accident Damage
- Delamination – large continuous area of the coating is removed from the part/area
 - Includes subcategories of CARC over CARC, Primer and Topcoat
- Needs Repaint – if the condition of the part requires repainting of the part/area
- Includes subcategories of Spot Painting (non-CARC), Coating Damage, Corrosion
- Faded – if, visually, the part/area appears to be faded due to ultraviolet (UV) radiation

of the data is used to evaluate criticality of the degradation, potential causes of the degradation, and maintenance actions that may be needed to restore the observed degradation. This information is also used to develop recommendations to prevent these degradations on future assets. Capturing corrosion data on existing assets enables PMs of future acquisition programs to identify shortcoming of current/legacy systems to the contractors, so better material, design, and manufacturing decisions can be made to mitigate/eliminate those issues.

Assessment Execution

Performing the assessments is a step-wise process, where the surveyor is led through specific steps to ensure the desired information is collected. This starts with capturing the asset

identification information (Figure 2). While the data is entered, simple checks are performed to ensure accuracy of the information entered (e.g., checking NSNs have 13 digits, making sure the bumper number and serial number fields are not blank, etc.). The survey also takes a photo of the data plate should an error occur (e.g., transposing numbers in an NSN or serial number).

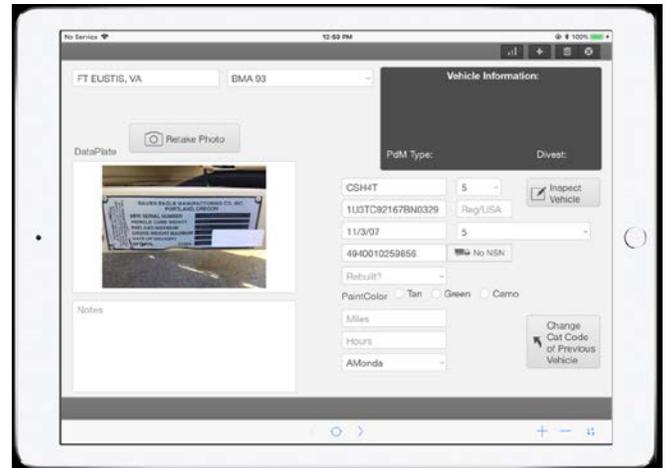


Figure 2. Asset Identification Information

After the identification data is captured, the surveyor begins their assessment by starting with an area of the asset. They start by taking a photo of the area to be inspected and provide general ratings for the overall condition (Figure 3). Depending on the asset type, they can inspect up to seven areas (Front, Rear, Interior, Top, Driver Side, Passenger Side, and Undercarriage). Areas that inherently do not exist on an asset (e.g., Interior on a trailer) are not inspected.

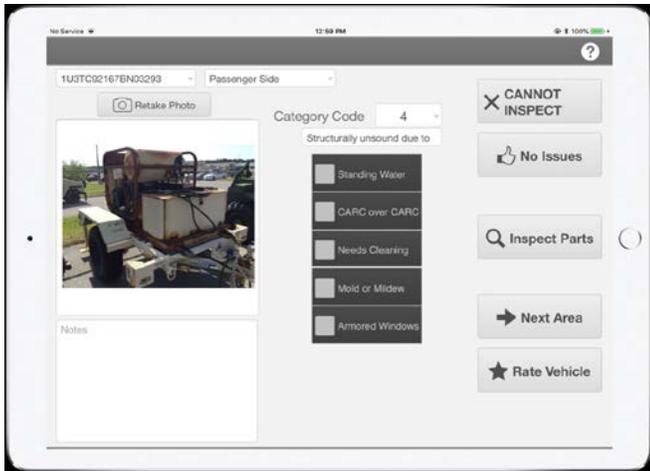


Figure 3. Asset Area Information

For each area, the surveyor records their observations for corrosion for specific parts (or groups of parts, such as for Fasteners). The surveyor selects a part name from a prepopulated list, or types a unique name if not included. They then record their observations of corrosion stage coverage, corrosion type, and coating degradation (Figure 4). The surveyor also takes photos of the part to document their observations, and can annotate the photos to record the condition of the part (Figure 5). There is no practical limit to the number of photos than can be taken for each part, other than device memory.

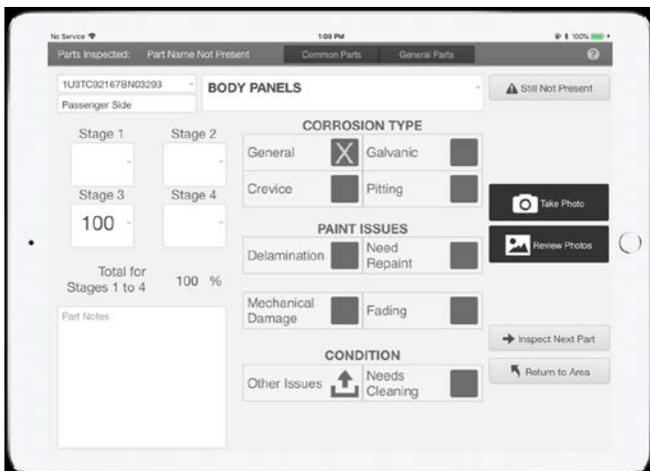


Figure 4. Part Corrosion Data

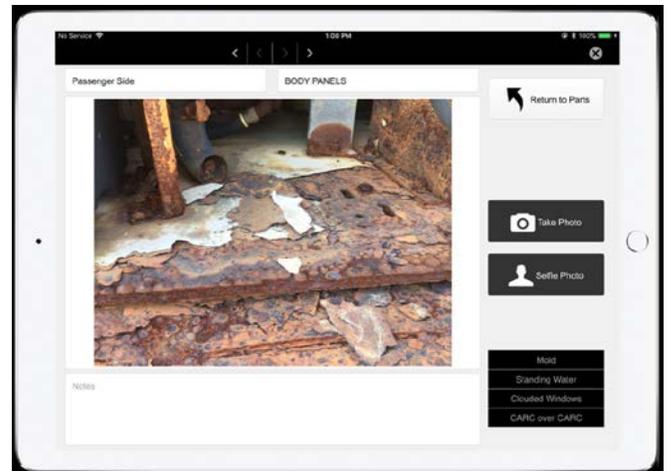


Figure 5. Part Corrosion Photograph

Once the surveyor has assessed all areas and parts for corrosion, they then assign an overall classification to the asset identifying if it needs:

- Corrosion Inhibiting Compound (CIC) Application or Spot Painting
- Complete Asset Repainting
- Metal Work to Repair Corrosion Damage
- Classification for the Level of Repair Needed

These classifications are provided in accordance with the Maintenance Information Message (MIM) DTG: 041851Z JAN 18.

Several continuous improvement mechanisms were established to establish, quantify, and improve the consistency and utility of the collected data. Inspection teams routinely meet to compare notes on new or unique observations, analytics on inspector ratings are evaluated, and database improvements are implemented.

DATA ANALYSIS AND REPORTING

Since the outset, it was desired to provide useful analysis and reporting based on the data collected at all levels of engagement. This starts with the installations and units where surveys are performed, the CPC Program, Army Materiel Command (AMC), and the Program and Product Managers (PMs and PdMs). Each of these groups

will have different needs and uses of the data collected.

Installation and Unit Reporting

The data collected is of value for the units and installation as it provides them with a general overview of the type of corrosion and coating degradation that is observed at their location. The overall ratings for the assets surveyed can also be used to assist in identifying maintenance needed. This information is provided to the installations at the end of the survey week, via an out-brief where a summary of vehicle classification is provided (Figure 6), examples of corrosion observations (Figure 7), near term opportunities to reduce corrosion (Figure 8), and the relative ranking to other locations (Figure 9).

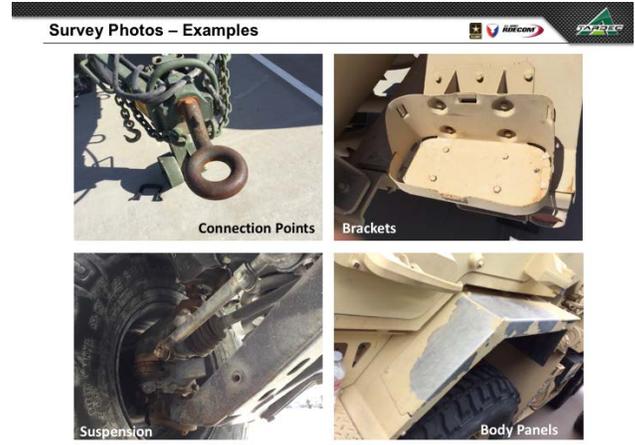


Figure 7. Examples of Corrosion and Coating Issues

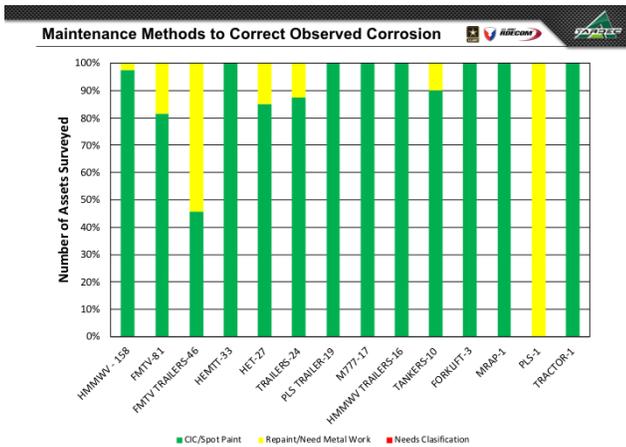


Figure 6. Classification of Assets by Corrosion Maintenance

Near-term Opportunities

- Items/areas for additional operator/user maintenance
 - Opportunity for use of CARC aerosol products for touch-up and registration marking
 - CARC aerosols include epoxy primer and polyurethane (CARC) topcoat
 - Washing/cleaning of undercarriages and other areas

Figure 8. Near Term Opportunities

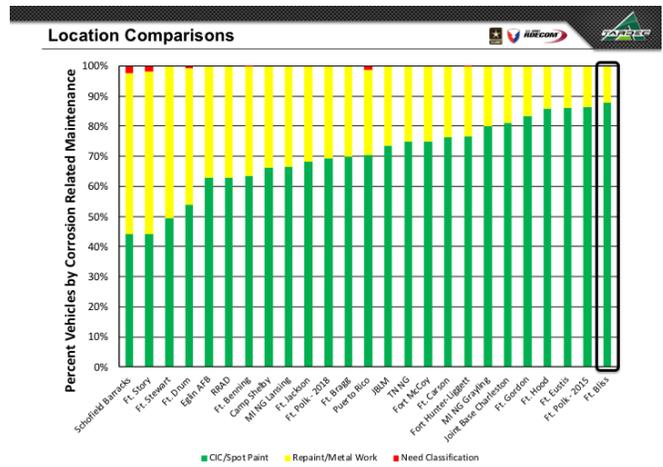


Figure 9. Relative Ranking of Installations by Corrosion Maintenance

Corrosion Surveys of Army Ground Assets to Identify Leading Issues and Opportunities for Corrosion Prevention

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In addition to an overall summary of the data collected, the installation and units are provided a corrosion survey dashboard. This is a Microsoft Excel™ file that allows units to review the data collected on their assets for ease of identification of which items need what types of maintenance by bumper/serial number, asset type, and unit (Figures 10 and 11).

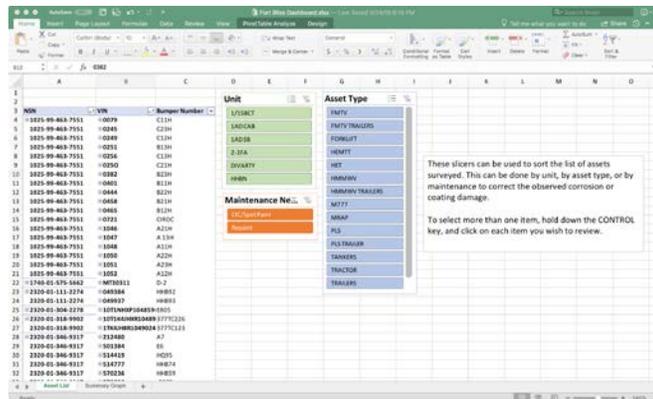


Figure 10. Corrosion Survey Dashboard - Asset List

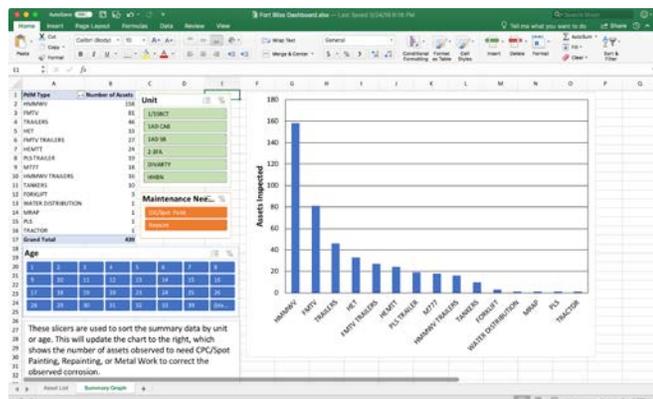


Figure 11. Corrosion Survey Dashboard - Summary Graph

CPC Program and AMC Reporting

Reporting provided to CPC and AMC builds upon the information provided to the installation and units. This includes comparisons to other corrosion assessment locations, to identify trends and leading issues. This includes analysis of the causes of corrosion as well as identifying maintenance procedures to correct current issues

and prevent future occurrences. This is provided for each installation within 45 days of completing a survey, and nominally on an annual basis for all locations surveyed to-date.

These formal reports, are intended to highlight leading observations of corrosion and the parts where most observations and/or the most severe observations have been made. These are tracked and continually updated, to reflect the findings across all locations. Consistently, four common parts (parts there are multiples of on an asset) appear in the top five most frequently observed items, and are:

- Brackets
- Connection Points
- Fasteners
- Wheels and Lugs

For general parts (parts that are asset specific or there are one or a few of on an asset), the top parts (by number of times they appear in the top 10 list) are listed in Table 1.

Table 1. General Parts Most Common Parts

Part Name	Times in Top 10
Body Panels	24 out of 24
Bumper	23 out of 24
Suspension	23 out of 24
Exhaust	21 out of 24
Frame	21 out of 24
Drivetrain	20 out of 24
Mirrors	19 out of 24
Steps	18 out of 24
Door Frame	13 out of 24

This information is used to highlight the most common issues across all platforms, with recommendations on how to reduce corrosion. Table 2 shows how corrosion observations on parts are mapped to potential solutions to corrosion prevention methods.

Table 2. Corrosion Prevention Methods Mapped to Corroded parts

Category	Issue	Chip-Resistant Coatings	Galvanized Shackles	Galvanized Wire Mesh	Encapsulating Lug Nuts	Improved Fastener Coatings	Improved Overcoating Procedures	CIC/CARC Spot Painting	LRC Maintenance	Engineering Change of GPK	Addition of Drain Holes	Priming Before Assembly	Engineering Change of Vent Cap	Running Light Gasket/Sealant
Common Parts	Connection Points	X	X				X	X					X	
	Wheels & Lugs				X	X	X	X						
	Brackets						X		X	X		X		
	Fasteners					X								
	Latches							X						
	Hydraulic & Air Lines & Connections							X						
	Suspension							X						
General Parts	Bumper	X					X	X	X					
	Frame								X					
	Body Panels						X	X	X					
	Cargo Bed Frame							X	X					
	Mirrors							X						
	Steps	X						X						

In the annual report, more details are provided for each of the proposed solutions. This includes:

- Areas of Benefit – where the proposed solution can/should be considered for use
- Implementation – general guidance on how to properly implement the material/maintenance method
- Expected Impact – what benefits can be expected from implementation (e.g., reduction in maintenance)
- Prior Demonstrations and Use – if the proposed solution has/is being used by the Army, other services, or if the material has previously been demonstrated on ground vehicles and weapon systems

Lastly, in both reports, any specific platforms that have been surveyed (at the request of a unit, installation, PdM, etc.) are highlighted. This includes specific findings, opportunities for corrosion prevention, and methods for remediation.

PM and PdM Reporting

Beginning in 2017, TARDEC has begun engaging PMs and PdMs and providing briefings on findings relevant to their materiel. These

briefings are formatted similar to the analyses provided to the CPC Program and AMC, but focus on issues found for specific asset types. This information is provided as an overall summary, with leading issues highlighted. These issues are accompanied by examples of the corrosion observed, potential causes, possible remediation methods, and implementation recommendations. This allows the PM/PdM to select items of interest to them, evaluate the potential impact corrosion has on their fleet, solutions to corrosion, and how best to implement those solutions. Solutions can include:

- Alternative finishes for parts
- Alternative base metal for parts or systems
- Changes to the coating systems used on an asset
- Changes to maintenance practices/frequencies
- Emphasis on/enforcement of existing corrosion prevention maintenance methods

CURRENT AND POTENTIAL USES OF ARMY CORROSION SURVEY DATA

As of May 2018, surveys have been conducted at 24 Army installations (including Regular Army [RA], National Guard [NG], and Army Reserves [AR]). Table 3 shows locations surveyed grouped by ISO Corrosivity Classification determined in accordance with ISO 9223.[2] The ISO Codes were reported by Leidos in their 2017 report classifying facilities environmental severity.[3] Figure 12 shows the survey locations and the asset classifications made during the surveys.

To date this has included:

- Surveying over 8,200 assets
- Evaluating over 121,000 parts
- Cataloging over 180,000 photos

This represents a significant accomplishment, with the collection of such a large and diverse data set.

Table 3. Survey Locations Grouped by ISO Code for Corrosivity.

ISO Code	Location	Assets Surveyed	Assets by ISO Code
C2	MI NG LANSING & GRAYLING	404	2,205
	FT HUNTER-LIGGETT, CA	413	
	FT MCCOY, WI	401	
	FT CARSON, CO	410	
	FT JACKSON, SC	139	
	FT BLISS, TX	438	
C3	FT BENNING, GA	383	4,129
	FT BRAGG, NC	331	
	FT DRUM, NY	425	
	FT HOOD, TX	312	
	FT POLK, LA (2015)	394	
	FT STEWART, GA	358	
	RRAD, TX	230	
	ARNG SMYRNA, TN	418	
	JOINT BASE LEWIS MCCHORD, WA	404	
	FORT POLK, LA (2018)	418	
	FORT GORDON, GA	187	
	FORT EUSTIS, VA	217	
FORT STORY, VA	52		
C4	SCHOFIELD BARRACKS, HI	402	796
	JOINT BASE CHARLESTON, SC	394	
C5	EGLIN AFB, FL	342	740
	PUERTO RICO	398	
UNK*	CAMP SHELBY, MS	419	419

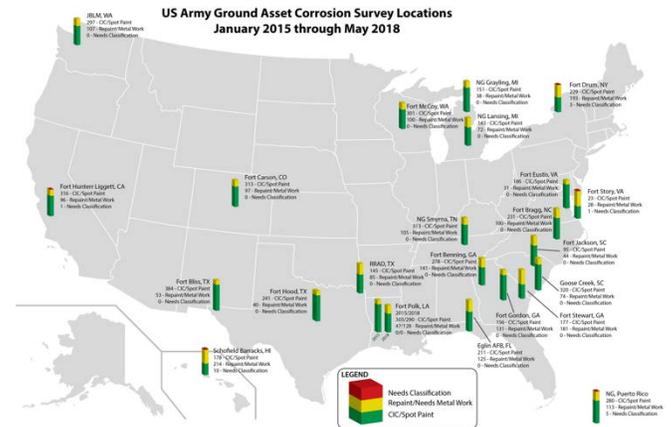


Figure 12. Map of Survey Locations and Asset Classifications

While the current use for the data has primarily been for reporting on the condition of assets, there exists other opportunities for this information. An example of this is in the development of corrosion awareness training. Such information is provided to units at each installation where a survey is conducted, and by performing surveys these trainings have been updated to provide more meaningful examples of corrosion that the Army faces, and highlighting the proper resources (e.g., TB 43-0213, “Corrosion Prevention and Control (CPC) for Tactical Vehicles”).[4]

Through the collection of corrosion data within the Army, and the identification of common issues, there exists the opportunity to improve the maintenance procedures used by units, Logistics Readiness Centers (LRCs), and depots for corrosion prevention and repair. This can be through refresher trainings on proper procedures for existing materials/processes, identification of better maintenance practices, or knowledge gaps that require additional research to solve a specific issue. Utilizing the collected data could aid the Army in making wise investments in maintenance and research budgets to reduce corrosion of their ground assets. For example, in 2016, it was estimated that \$1.2B (14.8%) of the Army’s spending on ground vehicle maintenance was due to corrosion.[5]

There are other opportunities to leverage this data for advancements in corrosion prediction methods, Condition Based Maintenance (CBM) tolls, etc. For example, the data has been provided for use in a continuing effort by TARDEC to develop an Accelerated Corrosion Expert System (ACES). This data will aid in the development of the models to predict corrosion issues on ground vehicles. The data may also be used to inform projects targeted at specific corrosion control initiatives.

CONCLUSIONS

The survey of Army ground assets has been successful, achieving the following:

- The Army CPC Program has surveyed the active Army ground vehicle fleet in accordance with the requirements of AR 750-59.
- The data collected has been used to identify leading issues across the Army and for specific platforms.
- TARDEC is engaging the PdMs for various platforms to identify opportunities to reduce corrosion on their assets.
- There exists a large dataset on Army ground vehicles that can be used to:
 - Identify corrosion trends,
 - Support training efforts for corrosion prevention and control,
 - Support maintenance and research investments, and
 - Support research projects in general.

There also exists the opportunity to understand the progression of corrosion over time as sites are

revisited. Collecting data at the same location over multiple visits will aid in understanding more than just the current condition of the fleet. It presents the opportunity to see how effective local practices are at preventing corrosion. While recommendations can be made on best practices for corrosion prevention using the current data, observing the progression of corrosion over time will aid in refining those choices as well as evaluating their long-term effectiveness.

The continued collection of this data represents a significant opportunity for the Army to both understand and prevent the corrosion occurring on their ground materiel.

REFERENCES

- [1] Army Regulation 750-59 “Maintenance of Supplies and Equipment – Corrosion Prevention and Control for Army Materiel,” Headquarters, Department of the Army, Washington, DC, 19 March 2012.
- [2] ISO 9223, “Corrosion of Metals and Alloys – Corrosivity of Atmospheres – Classification, Determination and Estimation,” International Organization for Standardization, February 2012.
- [3] N. Silver and W. Gaebel, “Facilities Environmental Severity Classification Study,” Leidos, February 2017.
- [4] Technical Bulletin 43-0213, “Technical Bulletin for Corrosion Prevention and Control (CPAC) for Army Wheeled Vehicles,” Headquarters, Department of the Army, Washington, DC, 24 September 2012.
- [5] E. Herzberg, “Estimated Cost of Corrosion on Cost and Availability of DoD Weapon Systems, FY18 Update”, LMI, March 2018.