THE IMPACT OF CORROSION ON THE AVAILABILITY OF DOD WEAPON SYSTEMS AND INFRASTRUCTURE

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Executive Summary

Corrosion negatively impacts the cost, safety, and readiness of equipment and infrastructure. The Corrosion Prevention and Control Integrated Product Team (CPC IPT), under the aegis of the DoD Director of Corrosion Policy and Oversight (CPO), has conducted studies over the previous 4 years to determine the cost-related impact of corrosion. Having developed a sound methodology and process for measuring the annual cost of corrosion, the time has come to determine if an equally viable method can be developed to measure the effect corrosion has on the readiness of weapon systems and facilities.

We partitioned DoD into 12 study segments (see Table ES-1) and pursued the availability and maintenance data for a representative weapon system or facility within each segment. We then determined whether the data supported a system-specific assessment of corrosion-related availability issues within each study segment and whether the data supported a DoD-wide study for all weapon systems and facilities within each study segment.

Table ES-1. Segments for Corrosion-Related Availability Study

Segment number	Service	Segment type	System or facility
1	Army	Aviation	UH-60L helicopter
2		Missiles	Patriot launcher
3		Ground vehicles	Family of medium tactical vehicles (FMTV)
4	Air Force	Aviation	C-130 transport aircraft
5		Facilities	Surfaced runways and taxiways
6	Navy	Aviation	FA-18C fighter
7		Ships	DDG-63 STETHEM
8		Facilities	Piers, wharves, and staging areas
9	Marine Corps	Aviation	FA-18C fighter
10		Ground vehicles	Light armored and amphibious assault vehicles
11		Facilities	Water storage and distribution

Note: Army facilities were designated as the 12th study segment, but sample facilities and data were not available during this initial assessment effort.

We requested from the services a 6-month sample of weapon system availability and facilities condition data for each study segment. From those data sets, we attempted to discern the amount of non-available time for each system or facility and how much of that time was a result of corrosion. Table ES-2 shows a summary of our findings.

Table ES-2. Summary of Impact of Corrosion on Availability Results

Segment	System or facility	Non-available days (all causes)	Non-available days due to corrosion	Corrosion-related percentage	Does data support a full-scale study?
Army ground vehicles	FMTV	537,053	34,179	6.4%	Yes
Marine Corps ground vehicles	Amphibious assault vehicle	24,314	486	2.0%	Yes
Army aviation	UH-60L helicopter	31,726[a]	2,716	8.6%	Yes
Navy and Marine Corps aviation	FA-18C fighter	148,197[a]	13,196	8.9%	Yes
Air Force	C-130 transport aircraft	1,431,433[a]	233,434	16.3%	Yes
Navy ships	DDG-63 STETHEM	0	0	Cannot determine	Yes[b]
Army missiles	Patriot missile system	4,895	347	7.1%	Yes
Army facilities	None	N/A	N/A	N/A	No
Navy facilities	Piers and wharves	N/A	N/A	N/A	No
Marine Corps facilities	Water storage and distribution	N/A	N/A	N/A	No
Air Force facilities	Runways and taxiways	Cannot determine	Cannot determine	Cannot determine	Possibly

Note: Navy and Marine Corps aviation data was combined and assessed collectively.

[a] The number of non-available days depicted in this table will exceed the actual number of non-available days experienced by the system during the sample data period due to the practice of listing multiple causes for each incident of non-availability.

[b] Yes, if Maintenance Figure Of Merit (MFOM) value is used instead of non-available days.

CONCLUSIONS AND RECOMMENDATIONS

Based on the data we were able to obtain, we conclude the following:

- Corrosion has a significantly greater impact on availability of aviation assets than other types of weapon systems.
- The data currently accessible does not support a DoD-wide study of the impact of corrosion on the availability of facilities.

- A full-scale study on the impact of corrosion on availability for the major aviation end items would be the most preferable next step in the assessment. There are three main reasons for this recommendation.
  - Each military service owns a significant amount of aviation end items, and those items comprise a considerable portion of warfighting capability within each service. A study of the impact of corrosion on aviation weapon systems would be valuable to each service.
  - Aviation data systems support a wide-scale study.
  - Corrosion has a significantly greater impact on the availability of aviation assets than any other type of weapon systems.

The data currently accessible supports a wide-scale study of the impact of corrosion on availability for ground vehicles, missiles, and ships, but a full-scale study may produce only limited value.

- Maintenance and availability data for Army missile and ground systems do not include details on the end item subsystems that are causing maintenance problems.
- Up to 10 percent of the maintenance records for Marine Corps ground vehicles have no defect code, and up to 27 percent of the remaining records have no first character for the defect code. These gaps in data make conclusions to the vehicle subcomponent level less certain.
- Navy ships experience almost all of their non-availability during scheduled depot maintenance periods, which can last more than a year. The effect corrosion has on actual non-availability is almost impossible to discern. Although we can conduct a risk assessment of how corrosion affects the ships' missions using an MFOM, such an assessment will not contain information related to the non-availability experienced as a result of corrosion.

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Chapter 1

Background and Study Methodology

Corrosion negatively impacts the cost, safety, and readiness of equipment and infrastructure. The Corrosion Prevention and Control Integrated Product Team (CPC IPT), under the aegis of the DoD Director of Corrosion Policy and Oversight (CPO), has conducted studies over the previous 4 years to determine the cost-related impact of corrosion. Having developed a sound methodology and process for measuring the annual cost of corrosion, the time has come to determine if an equally viable method can be developed to measure the effect corrosion has on the readiness of weapon systems and facilities.

This report parallels the four study objectives: discuss the current definition of readiness, discuss the reasons why measuring the readiness impact of corrosion is necessary, discuss the study methodology, and determine the DoD study segments for which a full scale study on the corrosion impact on readiness is viable.

CURRENT DEFINITION OF READINESS

Readiness, as defined in Joint Publication 1-02, focuses on operational (unit) readiness.[1] For the purposes of this effort, we define readiness as "materiel availability" as supported by the following definitions from Joint Publication 1-02:

- Materiel readiness—the availability of materiel required by a military organization to support its wartime activities or contingencies, disaster relief, or other emergencies.
- Materiel—all items (including ships, tanks, self-propelled weapons, and aircraft) necessary to equip, operate, maintain, and support military activities without distinction as to its application for administrative or combat purposes.

In addition, *materiel availability* is the lone sustainment Key Performance Parameter stipulated by the Joint Staff and the DoD acquisition community.

[1] Joint Publication 1-02 defines readiness as "the ability of U.S. military forces to fight and meet the demands of the national military strategy. Readiness is the synthesis of two distinct but interrelated levels: a. unit readiness—the ability to provide capabilities required by the combatant commanders to execute their assigned missions…derived from the ability of each unit to deliver the outputs for which it was designed; and b. joint readiness—the combatant commander's ability to integrate and synchronize ready combat and support forces to execute his or her assigned missions." *Joint Publication 1-02, Department of Defense Dictionary of Military and Associated Terms,* 12 April 2001 (as amended through 30 May 2008), p. 455.

While the term *materiel availability* normally excludes infrastructure, for our purposes, infrastructure is included. We define acceptable readiness for infrastructure as the current condition of the facility or infrastructure asset that supports the intended mission of the facility or asset without degradation in its capacity or capability, and without the facility or infrastructure asset posing a safety threat.

WHY MEASURE THE IMPACT OF CORROSION ON AVAILABILITY?

There are a number of reasons why measuring the impact of corrosion on availability is necessary:

- Identifying corrosion issues that decrease the availability of equipment and infrastructure to accomplish mission requirements will assist the warfighter.
- The lack of a corrosion impact on availability measurement has been noted as a shortfall of the DoD corrosion program by the Government Accountability Office (GAO).
- There is a potential relationship between the corrosion impact on cost and availability.

Assisting the Warfighter

Availability is an important measured deliverable within the DoD community. The military services cannot accomplish their missions unless weapon systems are ready at their full capability. Similarly, facilities, such as runways, bridges, and family housing, cannot support members of the military unless they are safe to use and have retained their originally designed capability. Another potential byproduct of corrosion is the degraded availability of DoD's operational forces.

Previous studies have quantified DoD's cost of corrosion at approximately $22.5 billion annually.[2] While the financial cost of corrosion is approximately 23 percent of DoD's total maintenance costs (estimated to be $92 billion annually), we cannot assume that eliminating corrosion will increase the availability of equipment and infrastructure by 23 percent.

Essentially, military units must achieve the targeted availability at the lowest possible cost. Availability goals must be met first, with cost reductions to follow.

To the degree that corrosion is proven to be a degrader of unit availability, especially for units that struggle to meet their availability targets, it is more likely to receive the resources and attention necessary to reduce its negative effects, more so than if corrosion only affected cost. Therefore, additional study is required to

[2] *DoD Annual Cost of Corrosion*, Department of Defense Report, page v.

determine the extent of the impact corrosion has on availability and to provide detailed and actionable data.

Addressing the Shortfall Identified by GAO

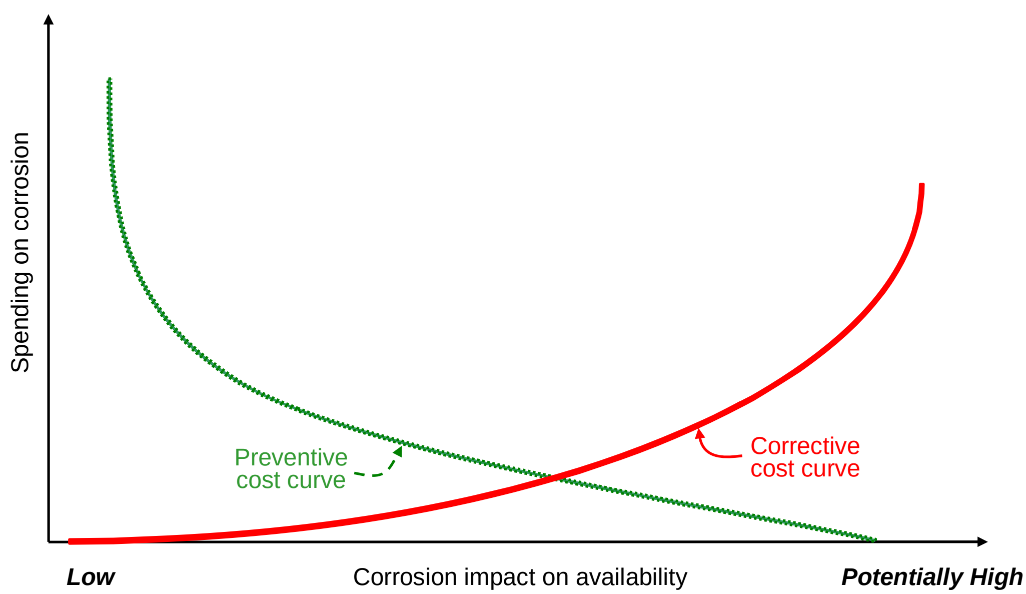
In a recent audit of DoD's corrosion program, the GAO noted that DoD has made some progress in identifying corrosion-related costs, but also noted the department still has not identified the effects corrosion has on availability and safety.[3] In the same report, the GAO relayed that DoD officials have said "some of their efforts will shift to availability and safety as the cost impact study approaches completion."[4]

It has been the intent of the DoD Corrosion Office to establish a viable method for measuring the cost impact of corrosion first and then develop a method for measuring the effects of corrosion on availability as the cost study neared completion. The CPC IPT completed its measurement of the cost impact of corrosion for all segments of DoD in July of 2009. The timing is right to turn attention to developing a method to measure the impact of corrosion on availability.

The Relationship between Cost and Availability

There is an apparent relationship between the effect corrosion has on costs and the effect it has on availability (see Figure 1-1).

Figure 1-1. The Relationship between Spending on Corrosion-Related Maintenance and Availability



[3] GAO, *High-Level Leadership and Actions are Needed to Address Corrosion Issues*, GAO Report 07-168, April 2007, summary page.

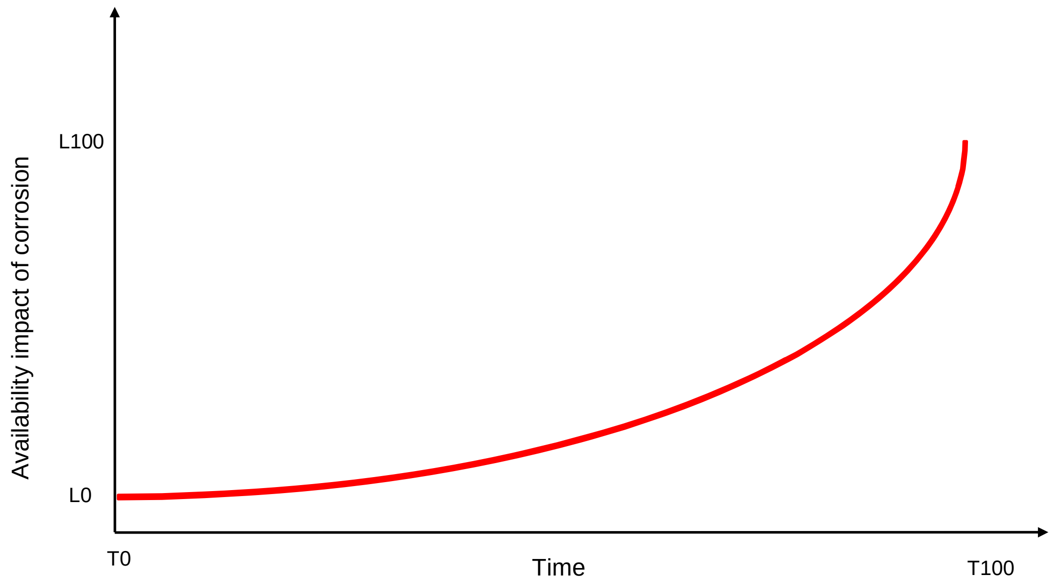
[4] Ibid, page 10.

From Figure 1-1, we see two relationships. The first is the relationship between spending on preventive corrosion and corrective corrosion.[5] Typically, this is an inverse relationship. The higher the amount of spending on preventive measures, the lower the corrective corrosion spending will be. The amount of preventive spending drives the resultant corrective actions. The exception to this general rule is there can be overspending on preventive measures without a corresponding reduction in corrective corrosion spending.

The other relationship is the amount of corrective corrosion cost and the subsequent impact on availability. Increasing amount of corrective corrosion spending can have a negative effect on availability. This is only a *potential* negative impact because organizational units could increase their efficiency when dealing with these unplanned corrective requirements or they could take exceptional measures (such as working an extensive amount of unplanned maintenance hours) to minimize the availability impact of corrective corrosion actions.

It is also useful to examine the effects on availability of not spending on corrosion. In Figure 1-2, we see the initial impact on availability of not spending any maintenance funds for corrosion. This initial impact is minimal. Over time, however, as corrosion starts to degrade all weapon systems and facilities at the same time, we see an accelerating impact on availability.

Figure 1-2. The Relationship between Zero Spending on Corrosion-Related Maintenance and Availability



Notes: L0 = initial level of corrosion impact on readiness; L100 = level of corrosion impact on readiness at time interval 100; T0 = start time; T100 = time interval 100.

[5] *Preventive costs* involve steps taken to remove the causes of potential nonconformities or defects. Preventive actions address future problems. *Corrective costs* are incurred when removing an existing nonconformity or defect. Corrective actions address actual problems. Source: International Organization for Standardization 9000:2000 definition of corrective and preventive actions.

STUDY METHODOLOGY

To ascertain whether corrosion has had a negative impact on the availability of weapon systems or facilities, two conditions must be present:

- The weapon system or facility must have experienced a loss in availability.
- Corrosion must be identified as a causal factor for that loss of availability.

If either condition is not met, we cannot say corrosion has had a negative effect. This is significant because corrosion could be a severe maintenance issue, but, as long as it does not result in the loss of the ability of the weapon system or facility to perform its intended function, the effect will be increased costs, not decreased availability.

We considered three main assessment methods to estimate the impact of corrosion on availability.

- *Assessment method 1*: Use actual availability or facility condition data that lists corrosion-related causes as availability degraders.
- *Assessment method 2*: Use actual availability data that lists the subsystems, parts, or facility condition issues that contribute to availability degradation. Use maintenance data to determine the impact of corrosion on these subsystems, parts, or condition issues. Combine the two data sets to estimate the corrosion impact on availability.
- *Assessment method 3*: Ask subject matter experts (SMEs) to determine which subsystems, parts, or facility condition issues are likely to cause availability degradation. Then, have the SMEs assess the likely corrosion relationship with these subsystems, parts, or facility condition issues. Finally, have the SMEs determine a ranking for the risk of corrosion impact on availability for each subsystem, part, or facility condition issue.

These three methods are listed in our order of preference. It is always more desirable to use actual data to establish a direct relationship between two variables than it is to infer such a relationship with separate but unrelated data sets or to rely on SMEs to estimate the relationship.

To make an informed decision about which method to use, it was necessary to examine the data that is available for each type of weapon system and facility within DoD—a daunting task.

Fortunately, we determined from the cost-of-corrosion studies that similar types of weapon systems within each service use the same maintenance reporting system. We assume this is also true for availability reporting. Therefore, we developed a plan to partition the DoD into 12 study segments just as we had in the cost-of-corrosion studies. We then obtained the availability data for a representative type of weapon system or facility within each segment and determined which assessment method could be used to determine the corrosion impact on availability.

Table 1-1 shows the study segments and the representative type of system or facility selected by each service for inclusion in this study.

Table 1-1. Weapon Systems and Facilities Selected by the Services

No.	Service	Segment type	System or facility	Identifier
1	Army	Aviation	UH-60L helicopter	LIN H32361
2		Missiles	Patriot launcher	LIN P11779
3		Ground vehicles	Family of medium tactical vehicles (FMTV)	Several LINs
4	Air Force	Aviation	C-130 transport aircraft	MDS C-130E or H
5		Facilities	Surfaced runways and taxiways	FAC 1111, 1113, 1121, 1131
6	Navy	Aviation	FA-18C fighter	TEC AMAF
7		Ships	DDG-63 STETHEM	Class DDG 551
8		Facilities	Piers, wharves, and staging areas	FAC 1511–1513, 1531
9	Marine Corps	Aviation	FA-18C fighter	TEC AMAF
10		Ground vehicles	Light armored and amphibious assault vehicles	TAMCN B1315, E0796, E0846, E0856
11		Facilities	Water storage and distribution	FAC 8413, 8421, 8432, 8434

Notes: DDG = guided missile destroyer; FAC = facility asset category; LIN = line item number; MDS = mission design series; TAMCN = table of allowance materiel control number; TEC = type equipment code.

Table 1-1 shows only 11 study segments. For example, Army aviation is segment 1, and Air Force facilities is segment 5. We designated Army facilities as the 12th study segment, but sample facilities and data were not available during the initial assessment effort.

We discuss the analysis of the data we collected for each study segment in the next chapter.

Chapter 2
Analysis of Data

Our goal was to determine the following for each weapon system or facilities segment:

- The assessment method that would best determine the impact of corrosion on availability for the selected weapon system or facility type.
- Whether the data systems for that study segment support a wide-scale study of the impact of corrosion on availability for all weapon systems or facility types within that study segment.

We grouped similar study segments together to conduct the analysis, and we portray the results by this grouping. We start with the facilities study segments.

FACILITIES

We pursued data for each of the facilities types selected by the services. The selected facility types are summarized in Table 2-1.[1]

Table 2-1. Facilities Types Selected by the Services for the Corrosion Impact on Availability Study

Service	Facility description	Facility asset code (FAC)
Navy	Pier	FAC 1511
	Wharf	FAC 1512
	Pier or wharf access trestle	FAC 1513
	Marine cargo staging area	FAC 1531
Air Force	Fixed wing runway, surfaced	FAC 1111
	Runway overrun area, surfaced	FAC 1113
	Taxiway, surfaced	FAC 1121
	Aircraft apron, surfaced	FAC 1131
Marine Corps	Water storage potable	FAC 8413
	Water distribution line	FAC 8421
	Water distribution line (fire)	FAC 8432
	Water pump facility	FAC 8434

[1] The Army facilities types were not available for this study.

Although there was no guidance given to each service on the facility types they could select for the study, each service selected facilities that could affect the accomplishment of the combat mission. For the Navy, the relationship between piers, wharves, and their naval fleet is clear. The same can be said of Air Force runways, landing areas, and their aviation fleet.

Not as clear is the relationship between the selected Marine Corps facility types and accomplishment of the combat mission. The Marine Corps' selection of water pump stations and distribution lines is related to the ability to supply water for fire fighting and other essential needs. They may not impact combat capability directly, but the non-availability of these pump stations and distribution lines certainly increases the risk of loss of life and property should a catastrophe, training accident, or direct attack occur.

The Best Method to Assess the Corrosion Impact on Facility Availability

To determine the corrosion impact on availability from the data provided for facilities, it was essential the data contain information on the physical condition of the facility, provide some description of the current physical condition problems, and indicate whether the facility could support its intended purpose in its current condition.

Navy and Marine Corps Facilities

We quickly ran into a problem obtaining data on the selected Navy and Marine Corps facilities. Although the Navy and Marine Corps have condition assessment data on many of their facility types, they do not have recent data for the facility types selected for this study. The "best" condition data available is for buildings and is contained in a database known as "Builder." This is a common database used by each service.

Because no condition data are available for the Navy facilities (piers and wharves) or for the Marine Corps facilities (water pumps and water distribution stations), the only assessment method available was to determine the impact of corrosion on the availability of these facility types using subject matter expertise. Coordinating this effort to estimate the impact of corrosion for the selected Navy and Marine Corps facility types was beyond the scope of this study.

Air Force Facilities

The Air Force did have condition assessment data for its selected facilities. The data is contained in a database called "MicroPaver" and is quite detailed. The physical condition of the runways, taxiways, and runway aprons selected by the Air Force for this study is routinely assessed by inspection teams at various Air Force bases.

The physical condition is portrayed through the use of the following two metrics:

- *Pavement condition index* (PCI) is a measurement of the current physical condition of the pavement.
- *Engineering Assessment* (EA) is a metric consisting of four factors.
  - PCI
  - Friction index, which measures the friction characteristics of runways
  - Structural index, which measures the potential damage a given aircraft is likely to cause a given pavement
  - Foreign object damage–potential, which measures the potential damage loose pavement could cause to a given type of aircraft.

Essentially, the PCI is an assessment of the current pavement condition and the EA is a more forward-looking metric that measures the risk of future pavement deterioration and potential damage to aircraft. Because this study is focused on the impact of corrosion on availability of facilities and requires current condition data for that assessment, we concentrated on PCI data.

PCI Assessment

Fixed sections of pavement are visually inspected for various defects. This data is entered into MicroPaver. Based on the defects found and the severity of those defects, a PCI score is determined for the section of pavement. Based on the total area measured, a PCI is then determined for the entire runway, overrun, taxiway, or apron. A final PCI for the installation is determined as well. Table 2-2 contains the range of PCI scores and their meaning.[2]

Table 2-2. Definition of PCI Scores

Range	Rating	Definition
86–100	Good	Pavement has minor or no distresses and will require only routine maintenance.
71–85	Satisfactory	Pavement has scattered low-severity distresses that need only routine maintenance.
56–70	Fair	Pavement has a combination of generally low- and medium-severity distresses. Maintenance and repair, or M&R, needs are routine to major in the near future.
41–55	Poor	Pavement has low-, medium, and high-severity distresses that probably cause some operational problems. Near-term M&R needs may range from routine up to a requirement for reconstruction.
26–40	Very Poor	Pavement has predominantly medium- and high-severity distresses that cause considerable maintenance and operational problems. Near-term M&R needs will be intensive.
11–25	Serious	Pavement has mainly high-severity distresses that cause operational restrictions; immediate repairs are needed.
0–10	Failed	Pavement deterioration has progressed to the point that safe aircraft operations are no longer possible; complete reconstruction is required.

[2] Applied Research Associates, Inc., *Airfield Condition Assessment Report*, Table 3-1, p. 3-1.

The Air Force has characterized its pavements into three categories and established minimum required PCI scores for each type of pavement. This is presented in Table 2-3.

Table 2-3. Air Force Pavement Characterization and Minimum PCI Scores

Pavement type	Description	Minimum PCI score
Primary	Critical to mission accomplishment	70
Secondary	Pavement that is not primary or tertiary	65
Tertiary	Pavement used for towing only	55

Decisions concerning maintenance funding and capital improvements to pavements are made with priority for pavements with PCI scores below the required threshold.

In Table 2-4, we show the PCI scores for a sample of 10 Air Force installations.

Table 2-4. Sample PCI Scores by Facility Type for Air Force Installations

Installation	Fixed wing runway, surfaced	Runway overrun area, surfaced	Taxiway, surfaced	Aircraft apron, surfaced	Overall average
Kessler AFB	93	N/A	81	73	81
Andrews AFB	81	75	76	83	81
Charleston AFB	61	16	84	81	77
Edwards AFB	63	79	64	68	66
Elmendorf AFB	72	86	77	82	79
Minot AFB	60	55	79	64	65
Osan AFB	54	74	84	81	77
Tinker AFB	90	67	83	65	74
Travis AFB	80	79	82	73	77
Tyndall AFB	94	61	87	85	87
Vandenberg AFB	98	99	94	95	97

Note: AFB = Air Force base.

Assuming the surfaced fixed-wing runways are labeled as primary pavements, with the other categories classified as secondary, and based on the Air Force minimum PCI scores, the shaded sections in Table 2-4 indicate pavements that would be in need of immediate attention.

Corrosion Impact on Availability of Air Force Pavements

To determine the answer to the question, "What is the corrosion impact on availability of Air Force pavements?" we repeat the criteria discussed in Chapter 1.

- The weapon system or facility must have experienced a loss in availability.
- Corrosion must be identified as a causal factor for that loss of availability.

Even as detailed as the data is in MicroPaver, we cannot assess whether a loss of availability was experienced without reviewing the project plans of each installation. We also would need to determine what corrective maintenance was actually performed on the pavements because, although a pavement may have received a low PCI score, it may not have been taken out of service or made non-available. Although a tedious task, it is possible to determine what corrective action was actually taken on these pavements.

The next step would be to consult with installation personnel to determine whether a loss of capability or capacity occurred as a result of the corrective pavement maintenance. Airfields are designed to provide redundant capacity. Even though one runway was not available for a period, it is possible other runways were available to absorb the loss in capacity and there was no effect on mission capability at the installation level.

If corrective maintenance was performed and resulted in a loss of mission capability for a time, an assessment of how corrosion contributed to the original PCI score would be needed. This is also possible because the pavement defects are well noted in MicroPaver, and corrosion-related defects (such as joint seal damage) can be determined. A percentage of the overall loss of availability could then be attributed to corrosion.

Therefore, for the four Air Force facilities types selected for this study, the best method to determine the potential impact of corrosion on availability is to use the MicroPaver data, combined with interviews of installation personnel and project management records. This is assessment method 2, combining two data sets to estimate the impact of corrosion on availability.

Do the Facilities Data Systems Support a Wide-Scale Study of the Impact of Corrosion on Availability?

In short, the answer is no. From the four facilities study segments (Army, Navy, Air Force, and Marine Corps), the impact of corrosion on availability of the selected facilities types could only potentially be determined for Air Force pavements. Even this estimation for Air Force pavements would have to be accomplished with assessment method 2, which is not the most robust analysis option.

WEAPON SYSTEMS

The Best Method to Assess the Corrosion Impact on Weapon System Availability

For assessment method 1 (the optimum choice) to be used to determine the impact of corrosion on availability, the data submitted for each weapon system must contain at least the following five data elements:

- Description of the weapon system end item or an identification code
- Description of the maintenance issue, either by code or text
- Indication of whether the maintenance issue resulted in a loss of availability for the weapon system
- Start time or date availability was lost
- End time or date availability was reacquired.

We conducted our analysis of the corrosion impact on availability for weapon systems by grouping similar study segments, such as ground vehicles or aviation assets. We begin with an analysis of Army and Marine Corps ground vehicles.

GROUND VEHICLES

We pursued data for each of the ground vehicle types selected by the services. The selected ground vehicle types are summarized in Table 2-5 and Table 2-6.

Table 2-5. Army Ground Vehicle Types Selected for Study

Model	Ground vehicle description	Identification code
M1078	Truck cargo	LIN T67578
M1078	Truck cargo 4×4 W/W	LIN T67748
M1083	Truck cargo MTV W/W	LIN T41135
M1083	Truck cargo W/O W	LIN T45051
M1083	Truck cargo MTV	LIN T61908
M1084	Truck cargo MTV W/MHE	LIN T41203
M1085	Truck cargo MTV LWB	LIN T61704
M1088	Truck tractor MTV	LIN T61239
M1088	Truck tractor	LIN T88847
M1089	Truck wrecker MTV W/W	LIN T94709

Table 2-5. Army Ground Vehicle Types Selected for Study

Model	Ground vehicle description	Identification code
M1093	Truck cargo 5-ton 6×6	LIN T41036
M1094	Truck dump 5-ton 6×6 MTV	LIN T65526

Notes: LIN = line item number; LWR = long wheel base; MHE = material handling equipment; MTV = medium tactical vehicle; W/O W = without winch; W/W = with winch.

Table 2-6. Marine Corps Ground Vehicle Types Selected for Study

Model	Ground vehicle description	Identification code
AAV	Amphibious assault vehicle	TAMCN E0796
AAV	Amphibious assault vehicle	TAMCN E0846
AAV	Amphibious assault vehicle	TAMCN E0856
LAV	Light armored vehicle	TAMCN E0942
LAV	Light armored vehicle	TAMCN E0946
LAV	Light armored vehicle	TAMCN E0947
LAV	Light armored vehicle	TAMCN E0948
LAV	Light armored vehicle	TAMCN E0949

Note: TAMCN = table of authorized materiel control number.

The Army chose 12 versions of its family of medium tactical vehicles (FMTV) for inclusion in this study. The Marine Corps chose three models of its amphibious assault vehicle (AAV) and five models of its light armored vehicle (LAV).

We compared the data we received for each system to the data elements required to determine which assessment method was most appropriate for determining the impact of corrosion on availability.

Army Ground Vehicles

The sample data for Army ground vehicles contains the necessary data elements to use assessment method 1 to determine the impact of corrosion on availability. This means the corrosion impact on availability can be determined directly from the availability data provided.

Within the data we collected, the depiction of the maintenance issue is a text field called the fault description. We used the same corrosion search words as we used in the cost of corrosion studies to flag vehicle records with a corrosion-related maintenance issue.

We present a summary of the maintenance data findings in Table 2-7.

Table 2-7. Maintenance Data Findings for Army Ground Vehicles Based on the FMTV Data Sample

Category	Values
Number of maintenance records	9,504
Percentage of records without text description	0.1%
Number of records with a corrosion-related maintenance issue	896
Percentage of records with a corrosion-related maintenance issue	9.4%

The next step was to assess both the corrosion and non-corrosion maintenance issues in terms of their impact on availability. The Army maintenance data we collected only depicts actions that resulted in a loss of vehicle availability. We show these results in Table 2-8.

Table 2-8. Impact of Corrosion on Availability of Army FMTV Based on Sample Data

Category	Values
Number of maintenance records	9,504
Number of maintenance records resulting in non-availability	9,504
Percentage of maintenance records resulting in non-availability	100.0%
Total non-available days—all maintenance issues	537,053
Total non-available days—corrosion maintenance issues	34,179
Percentage of non-available days attributed to corrosion	6.4%

Based on availability reporting data, corrosion is contributing to 6.4 percent of the total non-mission capable days for the Army FMTV.

Marine Corps Ground Vehicles

The sample data for Marine Corps ground vehicles contains the necessary data elements to use assessment method 1 to determine the impact of corrosion on availability. This means the corrosion impact on availability can be determined directly from the availability data provided.

The description of the maintenance issue is contained in the defect code field. It is a three-character alphanumeric field in which the first character depicts the major system on the vehicle on which the maintenance issue occurred. The second and third characters contain subsystem and maintenance issue descriptions.

Within the sample data for both the AAV and LAV, we identified four defect codes related to corrosion:

- Code 26—painting, body work
- Code 39—corroded/rusted
- Code 48—cracked, broken, or bent
- Code 58—moisture found.

Based on past experience from the cost-of-corrosion studies, we determined 100 percent of the occurrences of codes 26, 39, and 58 are corrosion-related; 25 percent of the occurrences of code 48 are corrosion-related.

We present a summary of the maintenance data findings by major vehicle type (AAV and LAV) in Table 2-9. This will provide a basis for the discussion concerning the corrosion impact on availability.

Table 2-9. Maintenance Data Findings Based on Sample Data for the AAV and LAV

Category	AAV values	LAV values
Number of maintenance records	3,502	1,626
Number of unique defect codes contained in records	59	64
Percentage of records without a defect code	4.8%	9.5%
Number of maintenance records with a defect code	3,334	1,472
Number of records with corrosion fault codes	122	31
Percentage of records with corrosion fault codes	3.7%	2.1%

A fairly significant number of records do not contain a defect code (4.8 percent of AAV repairs and 9.5 percent of LAV repairs). We eliminated these records from consideration in this analysis.

Further analysis showed only a small percentage of the maintenance records for both the AAV (3.7 percent) and LAV (2.1 percent) involve a corrosion fault code.

We then assessed both the corrosion and non-corrosion maintenance issues in terms of their impact on availability. Unlike the Army ground vehicle data, which only contained information on maintenance actions that resulted in a loss of availability, the Marine Corps records show maintenance actions that resulted in a loss of availability and those that did not. We show these results in Table 2-10.

Table 2-10. Impact of Corrosion on Availability of Marine Corps LAV and AAV Based on Sample Data

Category	AAV values	LAV values
Number of maintenance records with a defect code	3,334	1,472
Number of maintenance records resulting in non-availability	578	324
Percentage of maintenance records resulting in non-availability	17.3%	22.0%
Total non-available days—all defect codes	13,474	10,840
Total non-available days—corrosion defect codes	391	95
Percentage non-available days attributed to corrosion	2.9%	0.9%

Based on availability reporting data, corrosion is only a minor contributor to loss of availability for both the AAV and LAV. Corrosion is a much higher cause of non-availability on the AAV than the LAV, with more than four times the non-available days (391 compared to 95) and a percentage of non-available days attributed to corrosion three times higher (2.9 percent compared to 0.9 percent).

AVIATION ASSETS

We pursued data for each of the aviation types selected by the services. The selected aviation types are summarized in Table 2-11.

Table 2-11. Aviation Types Selected by the Services for Study

Service	Model	Aviation system description	Identification code
Army	UH-60L	Medium lift utility helicopter	LIN H32361
Navy and Marine Corps	FA-18C	Fighter aircraft	TEC AMAF
Air Force	C-130	Transport aircraft	MDS C-130E/H

As a general rule for aviation non-availability data, when multiple causes contributed to a single incidence of non-availability, each cause was listed on a separate data row, with the total days of non-availability listed for each separate cause. Because no convention is established for designating which was the primary cause of the non-availability, we treated each cause equally. The result is an over-estimation of the total days of non-availability, but a fair assessment of the impact of corrosion on the non-available days relative to the other non-corrosion causes.

Army Aviation

We pursued data for the Army UH-60L, the aviation system selected for participation in the study.

We found the sample data we were provided contained all the necessary elements to use assessment method 1. We could determine the impact of corrosion on availability of this weapon system directly from the data provided.

The description of the maintenance issue is contained in a three-character field called “failure code.” We applied the same criteria for this failure code as we did for the Army aviation cost-of-corrosion study to determine which maintenance actions were corrosion-related. We present a summary of the maintenance data findings for the UH-60L in Table 2-12. Roughly one out of every seven maintenance records (or 13.7 percent) has a corrosion-related fault code.

Table 2-12. Maintenance Data Findings for Army Aviation Based on the UH-60L Data Sample

Category	Values
Number of maintenance records	15,125
Number of unique defect codes contained in records	160
Percentage of records without a failure code	0.1%
Number of records with corrosion failure codes	2,071
Percentage of records with corrosion failure codes	13.7%

We then assessed both the corrosion and non-corrosion maintenance issues in terms of their impact on availability. The Army availability data depicts only those maintenance incidences that resulted in unscheduled non-available days. We show these results in Table 2-13.

Table 2-13. Impact of Corrosion on Availability of Army UH-60L Based on Sample Data

Category	Values
Number of maintenance records	15,125
Number of maintenance records resulting in unscheduled non-availability	15,125
Percent of maintenance records resulting in unscheduled non-availability	100.0%
Total unscheduled non-available days–all failure codes	31,726
Total unscheduled non-available days–corrosion failure codes	2,716
Percentage unscheduled non-available days attributed to corrosion	8.6%

Based on the availability reporting data provided, corrosion is a contributing cause to 8.6 percent of the combined total of unscheduled non-available days for the Army UH-60L. Because the data set contains multiple causes of non-availability for a single incident and does not list the primary cause, we cannot conclude that eliminating corrosion as a cause of non-availability will result in an 8.6 percent improvement in the availability rate.

Navy and Marine Corps Aviation

We pursued data for the Navy and Marine Corps FA-18C, the aviation system selected for participation in the study.

We found the sample data we were provided contained all the necessary elements to use assessment method 1. We could determine the impact of corrosion on availability of this weapon system directly from the data provided.

The description of the maintenance issue is contained in three different data fields included in the data:

- How malfunction code
- Work unit code (WUC)
- Action taken code.

Based on these three descriptions of the maintenance action, we used the same criteria as we used for the cost-of-corrosion study to designate corrosion-related actions from these codes. We present a summary of the maintenance data findings for the FA-18C in Table 2-14.

Table 2-14. Maintenance Data Findings for Navy and Marine Corps Aviation Based on the FA-18C Data Sample

Category	Values
Number of maintenance records	36,554
Number of unique malfunction codes contained in records	>1,000
Percentage of records without a malfunction code	0.0%
Number of records with corrosion malfunction codes	11,970
Percentage of records with corrosion malfunction codes	32.7%

From Table 2-14, we can see that a fairly large percentage of the maintenance records involve a corrosion malfunction code.

We then assessed both the corrosion and non-corrosion maintenance issues in terms of their impact on availability. We show these results in Table 2-15.

Table 2-15. Impact of Corrosion on Availability of Navy and Marine Corps FA-18C Based on Sample Data

Category	Values
Number of maintenance records	36,554
Number of maintenance records resulting in non-availability	36,554
Percentage of maintenance records resulting in non-availability	100.0%
Total non-available days—all malfunction codes	148,197
Total non-available days—corrosion malfunction codes	13,196
Percentage non-available days attributed to corrosion	8.9%

Based on the availability reporting data provided, corrosion is a contributing cause to 8.9 percent of the combined total of non-mission capable days for the Navy and Marine Corps FA-18C. In fact, corrosion has a similar relative impact on availability for the Navy and Marine Corps FA-18C (8.9 percent) as it does for the Army UH-60L (8.6 percent).

Because the data set contains multiple causes of non-availability for a single incident and does not list the primary cause, we cannot conclude that eliminating corrosion as a cause of non-availability will result in an 8.9 percent improvement in the availability rate for the Navy and Marine Corps FA-18C.

Air Force Aviation

We pursued data for the Air Force C-130, the aviation system selected for participation in the study.

We found the sample data we were provided contained all the necessary elements to use assessment method 1. We could determine the impact of corrosion on availability of the C-130 directly from the data provided.

The description of the maintenance issue is contained in two different text fields: the “problem description” and “action taken” fields. Based on these two descriptive data elements, we used the same criteria as we used for the cost of corrosion study to designate corrosion-related actions from these text fields. We present a summary of the maintenance data findings for the C-130 in Table 2-16. A fairly large percentage of the maintenance records involve a corrosion fault code.

Table 2-16. Maintenance Data Findings for Air Force Aviation Based on the C-130 Data Sample

Category	Values
Number of maintenance records	62,442
Percentage of records with text description	100.0%
Number of records with a corrosion-related maintenance issue	21,358
Percentage of records with a corrosion-related maintenance issue	34.2%

We then assessed both the corrosion and non-corrosion maintenance issues in terms of their impact on availability. We show these results in Table 2-17.

Table 2-17. Impact of Corrosion on Availability of Air Force C-130 Based on Sample Data

Category	Values
Number of maintenance records	62,442
Number of maintenance records resulting in non-availability	61,904
Percentage of maintenance records resulting in non-availability	99.1%
Total non-available days—all maintenance issues	1,431,433
Total non-available days—corrosion issues	233,434
Percentage non-available days attributed to corrosion	16.3%

Based on availability reporting data provided, corrosion is a contributing cause to 16.3 percent of the combined total of non-mission capable days for the Air Force's C-130. Corrosion has a significantly higher relative impact on non-mission capable days for the Air Force C-130 than it does for either the Army UH-60L or the Navy and Marine Corps FA-18C.

As is the case for the Army and Navy and Marine Corps aviation assessment, the data set contains multiple causes of non-availability for a single incident and does not list the primary cause. We cannot conclude that eliminating corrosion as a cause of non-availability will result in a 16.3 percent improvement in the availability rate for the C-130.

NAVY SHIPS

We pursued data for the ship selected by the Navy for inclusion in this study—the DDG-6 STETHEM, a DDG-51 class destroyer.

Measuring availability for Navy ships will be a different type of analysis than that of other weapon systems. Because of the size of the vessel, availability reporting is usually done at the major subsystem level. Major ship subsystems include

- the hull structure,
- propulsion plant,
- electric plant,
- command and surveillance,
- auxiliary systems,
- outfit and furnishings,

- armament,
- integration and engineering, and
- ship assembly and support services.

Difficulty in Assessing Availability for Navy Ships

Very rarely is a major maintenance issue discovered that immediately renders the ship non-mission capable. Of course, because of the constant exposure to a corrosive salt water environment, ships can experience a significant deterioration in capability if corrosion is left unchecked.

To determine the impact of corrosion on the availability of the DDG-63 STETHEM, we returned to our criteria from Chapter 1:

- The weapon system or facility must have experienced a loss in availability.
- Corrosion must be identified as a causal factor for that loss of availability.

In nearly all cases, the largest block of time that Navy ships are not available to perform their missions is during a depot maintenance action. For aircraft carriers and submarines, this period of non-availability can last more than a year. Measuring the extent corrosion contributes to the amount of days a vessel is not available due to a depot maintenance action is a potential method to assess the impact of corrosion on Navy ship availability.

There are two problems with this approach. The first is the interval between depot maintenance actions for Navy vessels can be extensive—sometimes up to 5 years apart. Trying to assess the impact of corrosion based on a small data sample (such as the 6-month sample we requested for this study) can be problematic because the sample period may not include the depot maintenance action. In our case, the STETHEM did not undergo a depot maintenance action during the sample period.

The second issue is that, even if we analyze a vessel undergoing a depot maintenance action, there are so many systems within the vessel that might be undergoing maintenance at the same time that it is extremely difficult to determine which maintenance issue is the primary cause of the non-availability. It would be a guess at best to determine if corrosion was the cause of extending the stay of a vessel in the depot maintenance facility. In most cases, the corrosion work can be done at the same time as other required non-corrosion maintenance actions and does not extend the period the vessel is not available to perform its mission.

Maintenance Figure of Merit

Realizing these limitations, the Naval Sea Systems Command developed a method to measure the potential risk of a maintenance failure to vessel systems and subsystems to the overall operation and capability of the vessel. The Maintenance Figure of Merit (MFOM) is a mathematical model that uses the data contained in maintenance records to determine priorities of maintenance actions as well as current availability of Navy vessels.

In simple terms, the relationship of each subcomponent, component, subsystem, and system of a Navy ship is mapped in relation to each other, and their criticality to the overall operation of the ship is determined numerically. In addition, the current operating condition of each is assessed whenever there is an inspection or a maintenance issue. Therefore, when a maintenance issue arises on any of the subcomponents, components, subsystems, and systems, the MFOM is calculated to determine the overall impact of the current condition of that item on the mission and operating capability of the ship. This leads to a logical prioritization of resources for the repair or refurbishment of the item relative to other items.

While we cannot determine the effect of corrosion on ships' availability directly, we can use the MFOM to determine the impact corrosion has on mission accomplishment for Navy ships. This is assessment method 3, associating maintenance data to SME input incorporated into a computer model to assess risk to ships' availability and mission accomplishment.

Corrosion Assessment Based on MFOM

We received data from the Navy's primary field-level maintenance system, the Maintenance Materiel Management Open Architecture Retrieval System (3M OARS). Using the item identification detailed in 3M OARS, we were able to map each maintenance record to the MFOM system and produce a MFOM screening value. We then associated this screening value with each maintenance record from 3M OARS.

Each 3M OARS record was also assessed using two descriptive text fields to determine whether the maintenance issue was caused by corrosion. We used the same procedures as we used for the Navy ships cost-of-corrosion study to assess these records for corrosion.

We summarize the general maintenance results for Navy ships in Table 2-18. A fairly large percentage of the maintenance records involve a corrosion maintenance issue (26.5 percent).

Table 2-18. Summary of 3M OARS Maintenance Records for DDG-63 STETHEM

Category	Values
Number of maintenance records	5,787
Number of unique maintenance issues contained in records	500+
Percentage of records without a text description	0.1%
Number of records with corrosion-related maintenance issues	1,538
Percentage of records with corrosion-related maintenance issues	26.5%

We then assessed both the corrosion and non-corrosion maintenance issues in terms of their impact on availability based on the screening values. The screening value is between 0 and 100, with a lower value signifying a higher risk that the current condition of the item requiring maintenance will have an impact on the ship's mission accomplishment or availability. Screening values of 49 and below require immediate attention. We show these results in Table 2-19.

Table 2-19. Summary of 3M OARS Maintenance Records for DDG-63 Based on MFOM Screening Values

Category	Number of records	Percentage of total records	Average of records
Maintenance records	5,787		
Maintenance records with an MFOM screening value	5,786	99.9%	
MFOM screening value—all records			94.16
MFOM screening value—corrosion records			95.19
MFOM screening value—non-corrosion records			93.78
MFOM screening value of 49 and below	148	2.6%	
MFOM screening value of 49 and below that are corrosion-related	15	0.3%	

The average screening value for records with a corrosion-related maintenance issue is actually higher (95.19) than the maintenance records that are not corrosion-related (93.78). Of the 5,787 maintenance records, 148 had a screening value of 49 or below, signifying a maintenance issue that requires immediate attention. Of these, 15 records were related to corrosion.

Based on the MFOM screening value, which serves as a surrogate measure for availability reporting for Navy ships, only 0.3 percent (15 records of 5,787) of the maintenance records had corrosion-related issues that required immediate attention. None of these rendered the ship immediately non-mission capable.

Army Missiles

We pursued sample data for the Patriot missile system, the representative missile type selected by the Army for inclusion in the study. The Patriot has several major subsystems that comprise the total system. We list these in Table 2-20.

Table 2-20. Patriot Missile Systems and Major Subsystems Used for the Corrosion Impact on Availability Study

Model	Description	Line item number
OE349MRC	Antenna mast group	A80593
A/S99A1	Antenna mast group	A80637
MSQ-129	Command system tactical	C40814
MRC137	Command relay group	C60363
MRC147	Command relay group	C90546
MSQ104	Engagement control station	E08497
MSQ132	Engagement control station	E08747
MSQ133	Information coordination central	J52501
M901	Launching station	L46979
MPQ65	Radar set	R18701
MPQ53	Radar set	R18815
M1032	Semi-trailer general maintenance	S43871

We compared the data we received for each of these systems to the data elements required to determine which assessment method was most appropriate for determining the impact of corrosion on availability. The data for the Army Patriot missile systems contains the data elements necessary to use assessment method 1 to determine the impact of corrosion on availability. This means the corrosion impact on availability can be determined directly from the availability data provided.

The description of the maintenance issue is contained in a text field called "fault description." Although the data in this field is minimal, it does provide enough clarity to discern whether the maintenance action was caused by corrosion. We used the same corrosion words as we used for the Army aviation and missile cost-of-corrosion studies to identify the corrosion-related maintenance actions. We present a summary of the maintenance data findings in Table 2-21. A relatively small percentage of the maintenance records involve a corrosion issue.

Table 2-21. Summary of Maintenance Records for Patriot Missile System

Category	Values
Number of maintenance records	338
Number of corrosion-related records	28
Percentage of corrosion-related records	8.3%

We then assessed both the corrosion and non-corrosion maintenance issues in terms of their impact on availability. We show these results in Table 2-22.

Table 2-22. Impact of Corrosion on Availability of Army Patriot Missile System Based on Sample Data

Category	Values
Number of maintenance records	338
Number of maintenance records resulting in non-availability	338
Percentage of maintenance records resulting in non-availability	100.0%
Total non-available days—all defect codes	4,895
Total non-available days—corrosion defect codes	347
Percentage non-available days attributed to corrosion	7.1%

Based on availability reporting data, corrosion is only a minor contributor to the loss of availability for the Patriot missile system.

Do the Weapon System Data Systems Support a Wide-Scale Study of the Impact of Corrosion on Availability?

Army and Marine Corps Ground Vehicle Data Systems

Assuming the same type of data is available for all Army and Marine Corps readiness reportable ground vehicle systems as was provided for this assessment, a wide-scale study of the effect of corrosion on availability can be performed. However, a serious data shortfall in both reporting systems may minimize the usefulness of such an effort.

The utility of assessing the impact of corrosion on availability is improved significantly when the vehicle subsystems and subcomponents that are causing the maintenance issues are readily identified within the maintenance record. Army ground vehicle maintenance records make no provision for this. Marine Corps ground vehicle records identify the major vehicle subsystem in the majority records that have a defect code, but 26 percent of those records do not contain the first character of the code. This means there is no vehicle subsystem identified as the source of the maintenance issue.

Therefore, both Army and Marine Corps ground vehicle availability data would be useful in determining which vehicle types have corrosion issues that are contributing to a loss of availability. Army ground vehicle data does not provide detail to the vehicle subsystem level. Marine Corps data does provide this level of detail, but only for 74 percent of the records that contain a defect code.

AVIATION DATA SYSTEMS

Assuming the same type of data is available for all the services' aviation systems as was provided for this assessment, a wide-scale corrosion impact on availability can be performed. However, a serious data shortfall in the Army aviation reporting system will minimize the usefulness of such an effort.

The utility of assessing the impact of corrosion on availability is improved significantly when the aviation subsystems and subcomponents that are causing the maintenance issues are readily identifiable within the maintenance record. Army aviation maintenance records make no provision for this. The Navy, Marine Corps, and Air Force reporting systems contain a WUC that provides adequate detail on the aircraft subsystem that is the source of the maintenance issue.

This shortcoming in the Army aviation reporting system was identified in the initial cost-of-corrosion report and echoed by the Army working integrated product team that was formed in 2009 to exploit the data from the cost-of-corrosion study. A potential solution to this data issue has been proposed and would create a WUC type reporting structure for Army aviation records. The WUC would be determined based on the text description and parts information from existing records. The WUC data field would be populated from existing records after the maintenance work was completed and would not create any extra burden on the maintenance technicians.

NAVY SHIPS DATA SYSTEMS

Because detailed maintenance data can be mapped into the MFOM system, and the MFOM system has the architecture of each ship type built into its database, a wide-scale study of the impact of corrosion on availability of Navy ships can be performed.

Because the actual non-availability of most Navy ships occurs during a depot maintenance action, and the effect of corrosion on the duration of the maintenance action is nearly impossible to separate from the effect of other non-corrosion-related maintenance actions, the MFOM screening value will be the metric used to assess the impact of corrosion on availability of Navy ships instead of actual not-available days.

The screening value is useful to rank the priority of maintenance actions, causes, subcomponents, components, subsystems, and systems relative to each other, but these screening values do not translate into actual days of non-availability.

ARMY MISSILES DATA SYSTEMS

To the extent availability data for other missile systems exist in the Army's Logistics Information Warehouse in detail that is equivalent to what was provided for the Patriot system, a full-scale study on the impact of corrosion on availability can be performed. The same shortcoming that exists for Army ground vehicle data exists for Army missile data. There is no work breakdown structure detailed in the maintenance records. This means the overall impact of corrosion on availability can be determined for each end item, but not for the subsystems or components that are actually causing the problem.

We did receive other non-availability data from the Army on the Patriot that contained work breakdown structure information to the part level; however, this data contained no text information to describe the maintenance issue. It did contain three fault codes (4, 70, and 450), but the respective fault code descriptions ("Low GM [transconductance] or emission," "broken," and "open" respectively) provide no insight into the relationship between corrosion and the reported maintenance issue.

Chapter 3
Summary, Conclusions, and Recommendation

In Chapter 1, we listed three assessment methods that could be used to determine the impact of corrosion on availability of weapon systems and facilities. In order of preference, they are as follows:

- *Assessment method 1*: Use actual availability or facility condition data that lists corrosion-related causes as availability degraders.
- *Assessment method 2*: Use actual availability data that lists the subsystems, parts, or facility condition issues that contribute to availability degradation. Use maintenance data to determine the impact of corrosion on these subsystems, parts, or condition issues. Combine the two data sets to estimate the corrosion impact on availability.
- *Assessment method 3*: Ask subject matter experts (SMEs) to determine which subsystems, parts, or facility condition issues are likely to cause availability degradation. Then, have the SMEs assess the likely corrosion relationship with these subsystems, parts, or facility condition issues. Finally, have the SMEs determine a ranking for the risk of corrosion impact on availability for each subsystem, part, or facility condition issue.

STUDY SUMMARY

We pursued data for each type of weapon system or facility selected by the services for inclusion in this study. We used the data we received to determine the impact of corrosion on availability for the weapon system or facility selected. We also assessed whether a full-scale study for all the weapon systems or facilities throughout DoD could be accomplished based on the data we received for the sample.

In Table 3-1, we summarize the results for each weapon system or facility.

Table 3-1. Summary of Impact of Corrosion on Availability Results

Study segment	System or facility selected	Non-available days (all causes)	Non-available days due to corrosion	Corrosion-related percentage	Does data support a full-scale study?	Comments
Army facilities	None	N/A	N/A	N/A	No	Sample facilities not available
Navy facilities	Piers and wharves	N/A	N/A	N/A	No	Condition data not available
Marine Corps facilities	Water storage and distribution	N/A	N/A	N/A	No	Condition data not available
Air Force facilities	Runways, taxiways, and aprons	Cannot determine	Cannot determine	Cannot determine	Potentially	Need to use assessment method 2
Army ground vehicles	FMTV	537,053	34,179	6.4%	Yes	Impact can only be determined to the end item level
Marine Corps ground vehicles	Amphibious assault vehicle	24,314	486	2.0%	Yes	Only 74 percent of records have sub-system-level detail
Army aviation	UH-60L helicopter	31,726[a]	2,716	8.6%	Yes	Impact can only be determined to the end item level
Navy and Marine Corps aviation	FA-18C fighter	148,197[a]	13,196	8.9%	Yes	Data supports determination of impact to sub-system level
Air Force aviation	C-130 transport aircraft	1,431,433[a]	233,434	16.3%	Yes	Data supports determination of impact to sub-system level
Navy ships	DDG-63 *Stethem*	0 non-available days	0 non-available days	Cannot determine	Yes, if MFOM value is used instead of non-available days	Non-availability only occurs during planned mainte-nance periods
Army missiles	Patriot missile system	4,895	347	7.1%	Yes	Impact can only be determined to the end item level

[a] The number of non-available days depicted in this table will exceed the actual number of non-available days experienced by the system during the sample data period. Multiple causes of non-availability will be listed in the data for the same incident. It is impossible to tell from the sample data the primary cause of the non-availability, so all causes were included. Non-available days due to corrosion were tallied in the same manner. Therefore, the relative impact of corrosion on availability measured as a percentage of the overall impact for all causes is still a valid comparison, but the total number of non-available days will be overstated.

STUDY CONCLUSIONS

Based on the summary presented in Table 3-1, we arrived at the following conclusions:

- Corrosion has a significantly greater impact on availability of aviation assets than other types of weapon systems.
- The data currently accessible does not support a DoD-wide study of the impact of corrosion on the availability of facilities.
- A full-scale study on the impact of corrosion on availability for the major aviation end items would be the most preferable next step in the assessment. There are three main reasons for this recommendation.
  - Each military service owns a significant amount of aviation end items, and those items comprise a considerable portion of warfighting capability within each service. A study of the impact of corrosion on aviation weapon systems would be valuable to each service.
  - Aviation data systems support a wide-scale study
  - Corrosion has a significantly greater impact on the availability of aviation assets than any other type of weapon systems.

STUDY RECOMMENDATION

A full-scale study on the impact of corrosion on availability of the major aviation end items would be the most preferable next step in the assessment of the effect corrosion has on the availability of weapon systems and facilities.

Appendix
Abbreviations

3M OARS	Maintenance Materiel Management Open Architecture Retrieval System
AAV	amphibious assault vehicle
AFB	Air Force Base
CPC	Corrosion Prevention and Control
CPO	Corrosion Policy and Oversight
EA	Engineering Assessment
FAC	facility asset code
FMTV	family of medium tactical vehicles
GAO	Government Accountability Office
IPT	Integrated Product Team
LAV	light armored vehicle
LIN	line item number
M&R	maintenance and repair
MFOM	Maintenance Figure of Merit
MTV	medium tactical vehicle
PCI	pavement condition index
SME	subject matter expert
TAMCN	table of allowance materiel control number
WUC	Work Unit Code