PROPOSED METHOD AND STRUCTURE FOR DETERMINING THE COST OF CORROSION FOR THE DEPARTMENT OF DEFENSE

SKT40T1

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Contents

Figures

Tables

Determining the Cost of Corrosion

Begin with the end in mind.
—Stephen R. Covey[1]

This report presents a method and structure for capturing the cost of corrosion for DoD. We start with a broad overview of the corrosion problem, including the effects of corrosion. We then approach these problems in a way that may seem counterintuitive—effectively beginning at the end, using cost information to frame discussions about the type of decisions that will be made. Understanding the types of decisions that will be made helps us determine which data elements are more useful than others for making the best decisions.

The data elements are prioritized by their decision-making value. We propose a structure for characterizing the corrosion cost elements, and discuss the importance of classifying corrosion costs as either preventive or corrective. In Appendixes A and B, we present suggested data sources, points of contact, and the maintenance reporting hierarchy for two proposed future studies of naval vessels and Army ground vehicles. We conclude with an outline of the cost-of-corrosion work elements that will help structure the effort for the two future studies presented in Appendixes C and D. These two appendixes are written so they can be detached from the body of this report and serve as standalone documents.

BACKGROUND

The cost of corrosion for DoD is estimated to be between $10 billion and $20 billion annually.[2] Although the military services have captured corrosion-related data in different forms for a number of years, there is no standard method or structure for compiling the information. Because corrosion costs—and opportunities for improvement—are high and the services face similar corrosion issues across common weapon systems platforms and facilities' infrastructure, it would be extremely beneficial to have a standard approach and structure for capturing corrosion costs.

[1] Stephen R. Covey, *The Seven Habits of Highly Effective People*, (Free Press, 1990).
[2] Richard Kinzie and Ruth Jett, *DoD Cost of Corrosion*, 23 July 2003, p. 3.

The Government Accountability Office (GAO) recommended this common approach in a recent report,[3] which stated the DoD corrosion strategy should

> also identify standardized methods for evaluating project proposals, estimating resource needs, and coordinating projects in an interservice and service-wide context.

DoD's Office of Corrosion Policy and Oversight, which is supported by the Corrosion Prevention and Control Integrated Product Team (CPCIPT),[4] is contemplating future cost of corrosion studies. This report identifies two initial areas for study and proposes a high-level standard method and approach.

We chose naval vessels and Army ground vehicles as the two areas of near-term study because there is ongoing detailed work to quantify the cost of corrosion for the Air Force, and we did not want to duplicate any effort. We also chose not to pursue the cost of corrosion for infrastructure[5] in this report because of sensitivity to the current Base Realignment and Closure (BRAC) planning and assessment.

The appendixes provide further information that is useful in tasking the activities that carry out the initial naval vessel and Army ground vehicle studies.

We begin with the end in mind by defining corrosion and its potential effects and then understanding how corrosion cost information will be used. Understanding how the cost information will affect decisions helps us define which cost elements are most valuable for making these decisions.

DEFINITION AND EFFECTS OF CORROSION

Corrosion is "the deterioration of a material or its properties due to a reaction of that material with its chemical environment."[6] Given that this definition is fairly broad, before DoD can develop a standard approach to capturing corrosion costs, it should understand how corrosion affects the warfighter.

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[3] GAO Report 03-753, *Defense Management: Opportunities to Reduce Corrosion Costs and Increase Readiness*, "GAO Highlights."

[4] Additional information about the DoD Office of Corrosion Policy and Oversight, as well as the CPCIPT, can be found at http://www.dodcorrosionexchange.org.

[5] Although we did not examine infrastructure, LMI maintains an infrastructure assessment model, I.CAM, that can calculate the replacement value of infrastructure and facilities. I.CAM uses the economic life of structures and facilities and the cost of projects to bring them back to their normal usefulness. This model could be valuable in calculating the cost of corrosion for infrastructure and facilities.

[6] Principal Deputy Under Secretary of Defense (Acquisition Technology and Logistics), Director, Corrosion Policy and Oversight, *Corrosion Prevention and Control Planning Guidebook*, pp. 1–4.

The effects of corrosion are seen in three areas: costs, readiness, and safety. We consider the tangible corrosion effects in each of these areas.

- Cost effects
  - Training
  - Direct man-hours (e.g., for inspection and repair)
  - Research and development (R&D)
  - Qualification process
  - Materials
  - Facilities
  - Test equipment
  - Accelerated rate of depreciation of assets
  - Scrap and disposal
- Readiness effects
  - Non-mission-capable days
  - Mission capability rates
  - Loss of training time
  - Degraded readiness (operational, but less than full capability)
  - Deferred maintenance days
  - Loss of weapon system operational time
- Safety effects
  - Loss of life
  - Accidents
  - Injuries
  - Aborted missions
  - Lower morale.

USE OF CORROSION COST INFORMATION

We agree with a July 2003 DoD cost of corrosion study, which states:

> It seems clear that adequate DoD corrosion costs can be captured, though the task may be formidable…However, the needs and use for such data would need to be clearly defined prior to any subsequent studies to determine the required fidelity and detail.[7]

Through our previous experience establishing cost systems and discussions with DoD corrosion experts, we identified five fundamental uses for corrosion cost information:

- To quantify the overall problem—This helps to determine the level of resources to apply to this issue both in funding and manpower, and provides a performance metric to assess effectiveness of the overall strategy to reduce the effect of corrosion.
- To prioritize efforts by the source of the problem—This helps determine which corrosion sources to attack first.
- To make project approval decisions and follow up on their effectiveness—Projects with the highest return on investment (ROI) are prioritized first and then once solutions are implemented, project leaders should track the before and after costs to help determine the effectiveness of the project.
- To maximize the overall effectiveness of maintenance activities by classifying the costs as either preventive or corrective.
- To determine potential design deficiencies and feed this information back to the acquisition community.

Although information in all three corrosion-effect categories (cost, readiness, and safety) are useful, priority needs to be placed on gathering cost information. Cost information is the most useful in making the decisions about corrosion efforts. Readiness and safety information cannot be used to judge the cost-benefit trade-offs on a project-by-project basis; nor can they be used alone to measure the scope of the corrosion problem or judge the overall effectiveness of a chosen corrosion mitigation strategy.

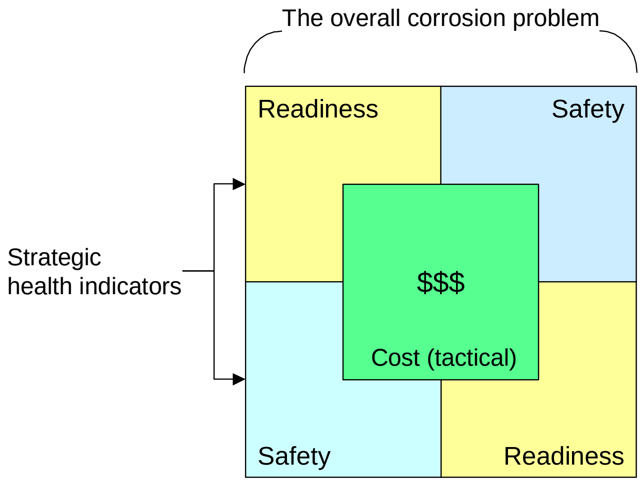
Focusing on obtaining cost information also eliminates the difficult issue of trying to turn non-cost measurements into costs. For example, imagine the difficulty in trying to put a value on the loss of life or a lost training opportunity. In DoD, quantifying the cost of non-mission capable systems is similarly elusive.

[7] Richard Kinzie and Ruth Jett, *DoD Cost of Corrosion*, 23 July 2003, p. 14.

Strategic Health and Tactical Cost Indicators

The readiness and safety information is still extremely valuable, and logically should be used as strategic health indicators, with the cost information a tactical indicator. The appropriate mix of these different indicators is depicted in Figure 1.

Figure 1. Strategic Health and Tactical Indicators for Corrosion



A strategic health indicator is a non-cost measure that, when reviewed and calculated consistently over time, provides insight into the overall progress of a strategic project. The indicator should be narrow enough that it directly correlates to the strategic issue at hand, but not too narrow that it is meaningless.

Table 1 lists a few examples of potential strategic health indicators for measuring progress with F-14 corrosion.

Table 1. Potential F-14 Strategic Health Indicators

Category	Too narrow	Too broad	Good fit
Readiness	F-14 degraded readiness days	F-14 mission capability rates	F-14 non-mission capable days due to corrosion
Safety	Corrosion complaints from F-14 pilots	F-14 accidents	F-14 accidents related to corrosion

A total of three or four appropriate strategic health indicators, in conjunction with the cost information, yield a thorough picture of the overall progress of the chosen corrosion strategy. Table 2 lists the potential strategic health indicators for the corrosion issue.

Table 2. Potential Strategic Health Indicators for Overall Corrosion Issue

Indicator	Effected area
Accidents related to corrosion	Safety
Non-mission-capable (NMC) days due to corrosion	Readiness
Number of lost operational hours due to corrosion	Readiness
Fatalities and injuries due to corrosion	Safety
Lost training time due to corrosion	Readiness
Deferred maintenance man-hours due to corrosion	Readiness

Use of Cost Information as a Tactical Indicator

Project leaders can use cost information in a tactical way to pick which battles to fight first, choose the level of resources to dedicate to each project, and predict the effect a project will have on overall cost. Cost as a tactical indicator is a useful measure to determine the effect of changes to potential root causes of corrosion. But not all costs are useful for these tactical decisions. Only costs that vary according to changes in root-cause corrosion conditions should be used.

Table 3 indicates which cost effects (listed earlier) are tactically useful.

Table 3. Identifying Tactically Useful Corrosion Costs

Cost effect	Tactically useful
Training	No
Research and development	No
Qualification process	No
Facilities	Potentially
Test equipment	Potentially
Direct man-hours	Yes
Materials	Yes
Accelerated rate of depreciation	Yes
Scrap and disposal	Yes

The first three cost effects—training, R&D, and qualification—are not tactically useful because, although they represent real costs, their costs and potential benefits are generally not attributable to a specific source of corrosion. While there are occasional exceptions (such as a training class that deals with a specific type of corrosion on a specific weapon system), the cost and benefits of training, R&D, and the qualification process typically are spread out over many different sources of corrosion and weapon systems.

Facilities and test equipment can be tactically useful in terms of their cost basis if their existence, and hence their expenses and potential benefits, can be closely tied to a single weapon system or root cause of corrosion, or can be allocated among a few weapon systems or root causes. For example, the cost of a hangar that keeps aircraft under cover has little tactical cost-of-corrosion benefit because it can be used by several aircraft and has many uses other than corrosion mitigation. However, the cost of a wash station for UH-60 helicopters is potentially useful because the costs and benefits associated with this facility can be tied directly to a single weapon system platform and the main purpose of the facility is to prevent corrosion.

Although an accelerated depreciation rate is a true and tactically useful cost effect of corrosion, we recommend treating the actual cost as a scrap and disposal cost. Up until an asset is declared “no longer useful,” the cost effects of using the asset in an environment that causes faster-than-average decay due to corrosion is a greater cost in terms of manpower, materials, test equipment, and facilities used to keep the equipment functioning.

We account for these costs in our proposed cost structure. Once the asset is declared “no longer usable,” it is scrap and will be disposed of. The cost of accelerated corrosion can then be calculated as a percentage of the normal useful life that could not be realized. A simple convention, such as a percentage of the replacement cost, can be used to calculate the cost of premature failure due to corrosion. Because this cost is only realized at the point it is considered scrap, we treat the cost as a scrap and disposal cost, and no longer list “accelerated rate of depreciation” as a separate cost effect.

Assuming the costs and benefits associated with some facilities and test equipment can be used in a tactical sense leaves the remaining cost elements as the most beneficial for tactical corrosion decisions:

- Facilities
- Test equipment
- Direct man-hours
- Materials
- Scrap and disposal.

Preventive and Corrective Costs

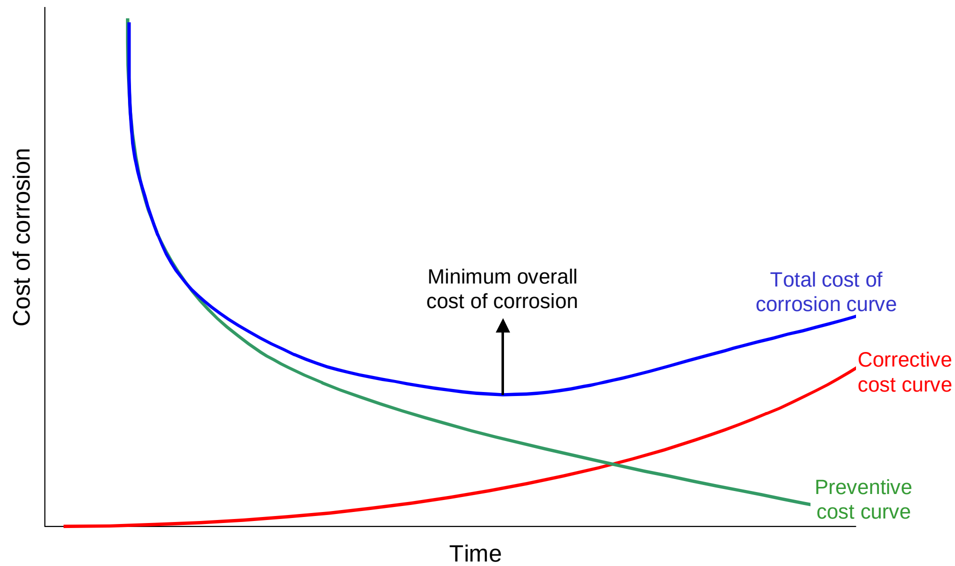
It is advantageous to further classify the cost elements into preventive and corrective (or reactive) costs:

- Preventive costs involve steps taken to remove the causes of potential nonconformities or to make quality improvements. Preventive actions address potential problems, ones that haven’t yet occurred. The preventive action process generally can be thought of as a risk analysis process.

- Corrective costs are incurred if you try to remove the causes of an existing nonconformity or to make quality improvements. Corrective actions address actual problems. The corrective action process generally can be thought of as a problem-solving process.[8]

From a management standpoint, it is useful to determine the ratio between preventive costs and corrective costs. Over time, it is usually more expensive to fix a problem than it is to prevent a problem. But it is also possible to overspend on preventive measures. As shown in Figure 2, classifying the cost elements into preventive and corrective categories helps leaders find the proper balance between these expenses to minimize the overall cost of corrosion.

Figure 2. Preventive and Corrective Corrosion Cost Curves

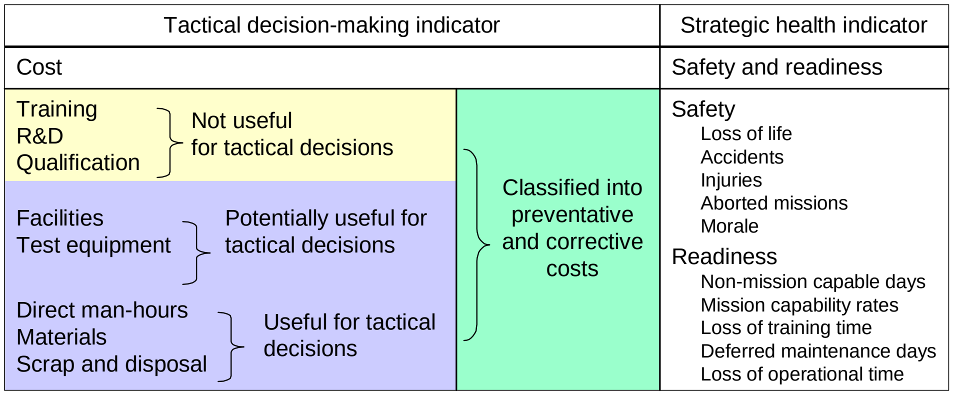


RECOMMENDED APPROACH

Given the earlier discussion of the types of decisions that will be made using the cost information and the use of strategic health indicators and tactical costs, we can begin to formulate a standard approach and priority for gathering cost information. This is depicted in Figure 3.

[8] International Organization for Standardization 9000:2000 definition of corrective and preventive actions.

Figure 3. Classification of Corrosion Effects by Decision-Making Usefulness



By determining the usefulness of the information relative to the decisions that would be made with the information, we can determine a priority for acquiring the different types of data depicted above. The priority ranking is provided in Table 4. In terms of cost, this yields the priority for gathering specific cost elements (Table 5).

Table 4. Priority of Acquiring Corrosion Information

Type of information	Priority to acquire
Tactically useful information	1
Potentially tactically useful information	2
Non-tactically useful cost information	3
Strategic health indicators	4

Table 5. Priority of Acquiring Corrosion Cost Information

Cost element	Priority to acquire
Direct man-hours	1
Materials	1
Scrap and disposal	1
Facilities	2
Test equipment	2
Training	3
Research and development	3
Qualification	3

We mentioned the value of classifying each cost element as either preventive or corrective. This could be an enormously challenging task, one that involves thousands of people trying to classify millions of activities and billions of dollars of cost in a standard method. However, keeping in mind that the value of classifying costs into preventive and corrective natures is to determine the ratio between these natures of cost, the classification does not require precision. To simplify, we can classify these cost elements now by their nature as depicted in Table 6.

Table 6. Classification of Corrosion Cost Elements into Preventive or Corrective Natures

Cost element	Corrective or preventive
Direct man-hours	Corrective or preventive
Materials	Corrective
Scrap and disposal	Corrective
Facilities	Preventive
Test equipment	Preventive
Training	Preventive
Research and development	Preventive
Qualification	Preventive

This leaves only the judgment of direct man-hours to be made on a case-by-case basis. To ensure consistency, direct man-hours attributed to corrosion are classified as preventive or corrective based on the following convention:

- Hours spent on the qualification process, research and development, inspection, and training are classified as a preventive cost.
- Hours spent using test equipment to check for the presence of corrosion are classified as a preventive cost.
- Hours spent at a facility built for the purpose of corrosion mitigation (such as a wash facility) are classified as a preventive cost.
- All other direct hours are classified as a corrective cost.

Now that we have determined the general cost elements, their usefulness and nature, we can determine a standard cost structure.

STANDARD COST STRUCTURE

The standard cost structure should fill the needs of decision makers in helping them make the decisions outlined in the Use of Cost Corrosion Information section above. The following is a recommended cost structure that will facilitate decisions about how to best mitigate the effects of corrosion:

- Data fields mandatory for all cost elements
    1. Performing activity
        a. Army
        b. Navy
        c. Air Force

d. Marines

e. Coast Guard

f. Contractor

g. Other

2. Nature of cost

h. Preventive

i. Corrective

3. Type of Cost

a. Training

b. Direct man-hours

i) Preventive

a) Inspection

b) Other

ii) Corrective

c. Research and development

d. Qualification

e. Materials—list type

f. Facilities

g. Test equipment

h. Scrap and disposal

4. Actual cost incurred

- Additional weapon system or facility data requirements for tactically useful cost information only

1. Weapon system type or facility type
2. Weapon system or facility unique identifier
3. Weapon system or facility age
4. Weapon system hours of usage

5. Weapon system subsystems using a work breakdown structure (WBS) down to as detailed a level as current systems allow
6. Unit
7. Location.

There is one exception: If qualification costs can be attributed to a single weapon system or subsystem, it is useful to capture the weapon system and subsystem information.

Table 7 depicts data fields required by cost element.

Table 7. Data Fields Necessary by Corrosion Cost Element

Cost element	Data fields	
	Mandatory data elements (perform activity, nature, type, actual cost)	Weapon system or facility data elements
Training	**X**	
R&D	**X**	
Qualification	**X**	If possible
Facilities	**X**	If possible
Test equipment	**X**	If possible
Direct man-hours	**X**	**X**
Materials	**X**	**X**
Scrap and disposal	**X**	**X**

COST STRUCTURE EXAMPLES

The following examples illustrate the cost structure outlined above. These two generic examples illustrate how corrosion costs can be structured so they provide valuable decision-making information. All numbers are for illustration only.

Situation 1: A total of 300 labor-hours are expended to repaint the hull of a 13-year-old aircraft carrier. The total corrosion costs would be a combination of the material and direct labor costs as follows:

- Material cost
  1. Service—Navy
  2. Nature of cost—corrective

3. Type of cost

   a. Materials—paint (The actual cost of the paint would be listed.)

   b. Materials—paint accessories[9] (The actual cost of the accessories would be listed.)

- Direct man-hours cost

  1. Service—Navy

  2. Nature of costs—corrective

  3. Type of cost—direct man-hours (The actual cost of the labor would be listed [hours times rate])

  4. Weapon system type—aircraft carrier

  5. Unique identifier—naval vessel #ABCDEFG

  6. Age—13 years old (or list date placed into service)

  7. Hours of usage—list hours here

  8. WBS breakdown—ESWBS 12000

  9. Unit—xxxx

  10. Location—yyyy.

Situation 2: A new engine seal is being qualified for use on several Army UH-60. The total corrosion cost is as follows:

1. Service—Army

2. Nature of costs—Preventive

3. Type of cost—Qualification (The actual cost of the labor would be listed [hours × rate] as well as any materials.)

4. Weapon system type—UH-60 helicopter

5. WBS breakdown—BFA92 engine seal.

[9] The use of the paint and accessories is not required to be tied to the unique naval vessel, but it is desirable if it can be done.

SUMMARY

Corrosion presents a significant challenge and opportunity that DoD must understand, control, and measure. This report details a method to characterize corrosion information, differentiates which information will be most useful for decision-making, and suggests a data structure to capture corrosion costs.

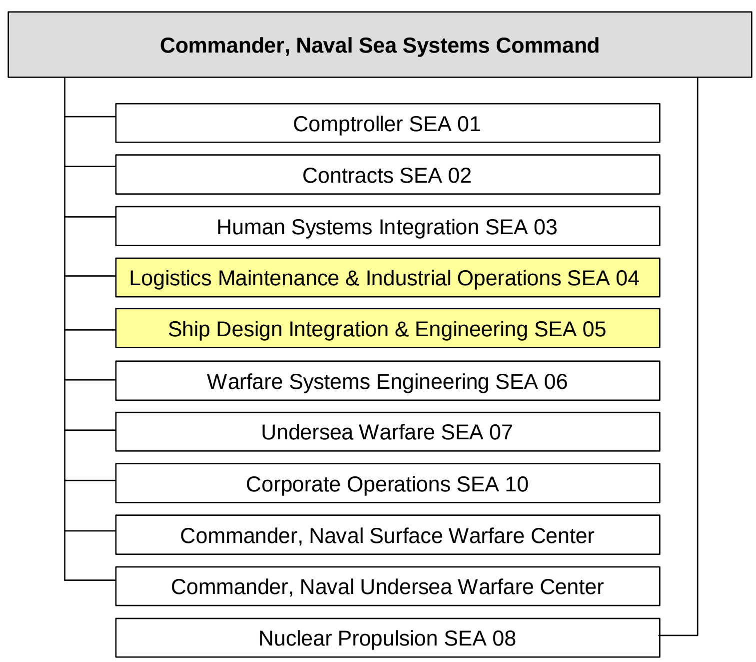
In the appendixes, we present information about the two initial study areas (naval vessels and Army ground vehicles), which will assist in a future detailed study effort that follows the method outlined in this report. Cost-of-corrosion work elements included in Appendixes C and D will assist in the structure of these future studies.

Appendix A
Naval Vessel Corrosion Cost Information

There are a variety of organizations involved in the planning and execution of maintenance for ships, ship systems, and ship weapon systems. A number of reporting systems collect information on various aspects of maintenance, including a few specifically related to corrosion control. Naval Sea Systems Command (NAVSEA) is the organization most focused on the acquisition and maintenance of Navy ships, submarines, and associated systems and equipment.

Within NAVSEA, the maintenance of ships and associated systems is not confined to a single organization. The offices most involved in maintenance are SEA 04, Logistics Maintenance and Industrial Operations, and SEA 05, Ship Design Integration & Engineering. Within SEA 05, there is a Corrosion Division (SEA 05M1), and within SEA 04, there is a Fleet Maintenance Policy and Process office (SEA 04M). The major directorates within NAVSEA headquarters are presented in Figure A-1.

Figure A-1. NAVSEA Command Structure



The following NAVSEA field activities perform maintenance functions or manage maintenance contracts:

- Norfolk Naval Shipyard, Portsmouth, VA
- Portsmouth Naval Shipyard, Portsmouth, NH
- Naval Surface Warfare Center, Crane, IN[1]
- Naval Undersea Warfare Center, Keyport, WA[2]
- Supervisor of Shipbuilding (SUPSHIP)[3]
  - Bath, ME
  - Pascagoula, MS
  - Ingleside, TX
  - Portsmouth, VA
  - Everett, WA
  - San Diego, CA
  - Newport News, VA
  - Groton, CT
  - Jacksonville, FL
  - New Orleans, LA
  - San Francisco, CA
  - Wallops Island, VA.

The following NAVSEA activities are involved with maintenance planning and engineering:

- Submarine Maintenance Engineering, Planning and Procurement Activity (SUBMEPP), Portsmouth, NH
- Naval Surface Warfare Center, Carderock Division, West Bethesda, MD
- Naval Sea Logistics Center, Mechanicsburg, PA.

[1] Primarily an engineering activity, but performs some maintenance.

[2] Primarily an engineering activity, but performs some maintenance.

[3] SUPSHIP offices that primarily administer maintenance contracts are being transferred to Fleet ownership, while those administering construction contracts remain in NAVSEA.

In addition, NAVSEA provides technical support to the following former NAVSEA-owned shipyards that have been transferred to Fleet ownership and combined with ship intermediate maintenance facilities:

- Pearl Harbor Shipyard and Intermediate Maintenance Facility, Pearl Harbor, HI[4]
- Puget Sound Naval Shipyard and Intermediate Maintenance Facility, Bremerton, WA.[5]

Navy ship maintenance can generally be categorized as organizational-, intermediate-, or depot-level, although the distinction between intermediate- and depot-level maintenance is becoming blurred with the consolidation of shipyards and intermediate maintenance facilities into single Fleet-owned[6] activities. Such consolidation has occurred in Pearl Harbor, HI, and is being accomplished in the Puget Sound, WA, area on a test basis.

ORGANIZATIONAL AND INTERMEDIATE MAINTENANCE LEVELS

Organizational maintenance is performed by ships' crews, either at sea or in port. Intermediate maintenance is accomplished at Fleet-owned maintenance facilities ashore, and is staffed almost exclusively by military personnel assigned to the maintenance activity. The intermediate maintenance facilities are capable of performing more complex work than can be done aboard ship at the organizational level. Ship maintenance performed at the organizational and intermediate levels is reported in the Material and Maintenance Management (3M) system.

The 3M system includes a code that identifies corrosion and codes that identify paint shop work and corrosion control shop work. Narrative descriptions sometime provide more definitive detail as to the precise cause or nature of repair work. The 3M data include labor hours and material costs to perform the maintenance. Labor hours must be priced out separately to get an estimate of the total direct cost of producing the work. The 3M system also identifies some maintenance work discovered by Fleet personnel that must be performed at the depot level, although the associated cost is rarely entered into the system. Data in 3M would partially satisfy priority-one data requirements (direct man-hours, materials, scrap and disposal) by providing direct labor hours and the cost of material related to corrosion problems.

[4] The Pearl Harbor Shipyard was converted to direct funding from Navy Industrial Fund operations, merged with the Intermediate Maintenance Facility, and transferred to Fleet ownership in FY99. NAVSEA continues to provide technical guidance.

[5] The Puget Sound Shipyard was converted to direct funding from Navy Industrial Fund operations, merged with the Intermediate Maintenance Facility, and transferred to Fleet ownership in FY04 on a test basis. NAVSEA continues to provide technical guidance.

[6] Commander in Chief, U.S. Atlantic Fleet (CINCLANTFLT), and Commander in Chief, U.S. Pacific Fleet (CINCPACFLT).

The 3M system is maintained at Naval Sea Logistics Center (NAVSEALOGCEN) in Mechanicsburg, PA. The primary points of contact regarding 3M data are

- NAVSEA 3M Program Manager—Mr. Phil Hans, (202) 781-3372; and
- NAVSEALOGCEN 3M Program Manager—Mr. Bill Casper, (717) 605-5666.

DEPOT MAINTENANCE LEVEL

Depot maintenance is the most complex repair work performed by civilian artisans at naval shipyards, other organic DoD depots, or commercial entities. Depot maintenance work on surface ships (except carriers) is reported in the Maintenance Requirements System (MRS), a system that is somewhat similar to 3M, although there is no specific corrosion code. Corrosion is identified by Expanded Ship Work Breakdown Structure (ESWBS) code or Ships Work Line Item Number (SWLIN) for work performed in public shipyards. Less detail is available for work performed by commercial contractors. The database is maintained by the Supervisor of Shipbuilding in Portsmouth, VA, and would partially satisfy priority-one cost data requirements by providing direct labor hours and the cost of material related to corrosion problems.

The primary points of contact regarding MRS data are

- Fleet Maintenance Policy and Process—Mr. Ken Jacobs (SEA 04M1), (202) 781-3382;
- MRS expert at NAVSEA HQ—Mr. Rob Sears (contractor at NAVSEA), (703) 460-1194; and
- MRS data maintenance SUPSHIP, Portsmouth, VA—Mr. Terry Wong, (757) 396-3796.

Other Depot Reporting Systems

For depot maintenance on carriers, data similar to what is available from MRS is maintained at the Carrier Planning Activity in Newport News, VA; and data for depot maintenance work on submarines is maintained at the Submarine Maintenance Engineering, Planning, and Procurement Activity (SUBMEPP) in Portsmouth, NH. Points of contact regarding depot data for carriers and submarines are

- Carrier Planning Activity, Newport News, VA—Mr. Joel Korzun, (757) 967-6123;
- SUBMEPP, Portsmouth, NH—Mr. Gary Jewell, (207) 438-6144; and
- Commander, Submarine Force, U.S. Atlantic Fleet (COMSUBLANT)—Mr. Willy Olmo, (757) 836-1390, olmoc@hq.sublant.navy.mil.

Other Potential Corrosion Information Sources

Three databases specifically target corrosion, focusing on coating information, but contain no actual cost information:

- NAVSEA Paint and Preservation Management Information System (NPPMIS). Point of contact is Mr. David Meikle, (202) 781-3667.
- Corrosion and Control Information Management System—Carriers (CCIMS [CV/CVN]). Data is maintained at the Carrier Planning Activity, Newport News, VA, and used by Commander, Naval Air Forces Pacific (CNAP) and Commander, Naval Air Forces Atlantic (CNAL). Point of contact is Mr. Joel Korzun, Carrier Planning Activity, Newport News, VA, (757) 967-6123.
- Corrosion and Control Information Management System—Submarines (CCIMS [Sub]). Data is maintained at and primarily used by SUBMEPP. Point of contact is Mr. Gary Jewell, SUBMEPP, Portsmouth, NH, (207) 438-6144.

These databases contain information on the percentage of system failure, location of installation, coatings applied, etc.

Propulsion and Power Generation Databases

There are three additional databases that contain maintenance information related to propulsion and power generation systems but do not include cost data: the Boiler Inspection and Repair Management Information System (BIRMIS), Gas Turbine (GT), and Diesel (DSL). These databases are maintained by the Naval Surface Warfare Center, Carderock Division (NSWCCD, formerly the Naval Ship Systems Engineering Station), in Philadelphia, PA. Points of contact for these databases are

- Branch Head, code 622—Ms. Terry Steck, (215) 897-7484; and
- Analyst, code 622—Mr. Mike Gallagher, (215) 897-7314.

NAVY-WIDE OPERATIONS AND MAINTENANCE REPORTING SYSTEM

The Visibility and Management of Operation and Support Costs (VAMOSC) system is a Navy-wide reporting system of operating and maintenance costs collected from many different sources designed to identify the cost of ownership by weapon system and subsystem. VAMOSC data cover only major weapons systems and the system does not identify specific corrosion issues; but it does list ESWBS for work performed at organic (public) shipyards, which often identifies corrosion-related work. Maintenance data reported in VAMOSC are reported in 3M, MRS, or one of the other databases that collect information on depot maintenance.

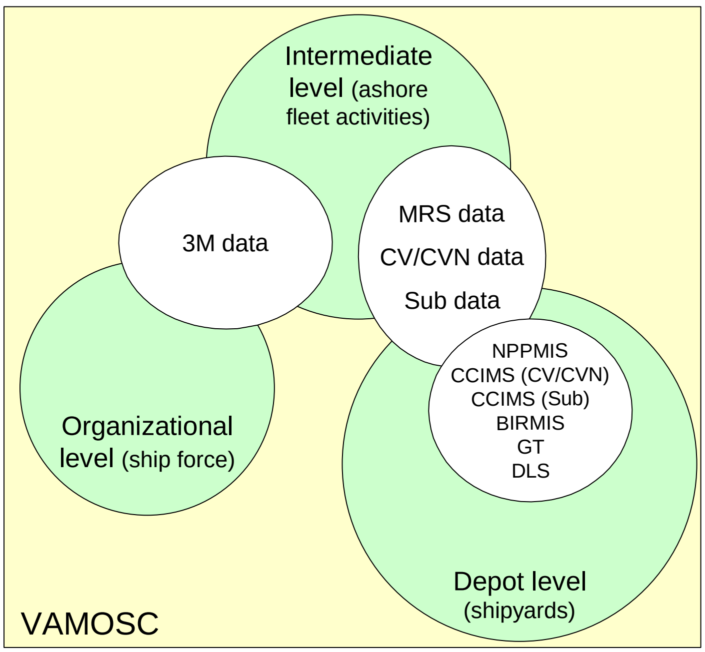
Points of contact regarding VAMOSC data are

- Naval Cost Analysis Division (FMB-6)—VAMOSC ships/shipboard system contact, Mr. Mike Carey, (703) 692-4901, michael.j.carey@navy.mil; and
- VAMOSC user at Naval Surface Warfare Center, Carderock Division—Mr. Michael Gallagher, GallagherMR@nswccd.navy.mil.

SYSTEM INTERACTION

Figure A-2 portrays the basic relationships of the systems discussed above.

Figure A-2. Mapping of Information System by Maintenance Level for Naval Vessels



The established reporting systems and databases in Figure A-2 focus on maintenance actions, either required or executed. These databases do not include information on indirect costs (such as training, research and development, qualification, facilities, test equipment, or scrap and disposal). Some of these indirect costs may be included in overhead costs charged by Defense Working Capital Fund activities for maintenance work and in costs for contractually obtained maintenance, although generally they are not identified specifically.

We recommend a study of corrosion costs begin with an examination of maintenance data reported via 3M, MRS, and the two similar databases for carrier and submarine maintenance (CCIMS [CV/CVN] and [Sub]). These databases identify a significant amount of total costs for maintenance on ships, submarines, and related systems for corrosion-related maintenance. These databases generally identify labor and material (and sometimes overhead) costs but do not provide data for all the priority-one cost elements. Also, data related to work performed by commercial contract contains less detail than data related to work performed in DoD facilities, and corrosion-related maintenance might not always be correctly identified.

A recent site visit to Portsmouth, NH, indicated that "99 percent of all ballast and hull (submarine maintenance) work was within the definition of corrosion maintenance, regardless of the skills employed or the coded reason for their efforts."

Identification of all priority-one cost information for all desired cost elements requires a more comprehensive approach. Given the current interest in corrosion-related costs, we recommend a formal reporting requirement be established to gather corrosion-related cost data. Existing systems provide a core source of that information for maintenance-related actions, but cost accounting systems may need modification to routinely identify additional requested information. Input is needed from the Chief, Education and Training Command (CNET), Commander in Chief U.S. Pacific Fleet (CINCPACFLT), and the Commander in Chief, U.S. Atlantic Fleet (CINCLANTFLT), for the cost of training of military members; and input is needed from the Office of Naval Research (ONR) for research projects related to the problem of corrosion.

The following are key points of contact for the general issue of corrosion within NAVSEA:

- Navy CPCIPT representatives—Primary contact: Dr. Robert Pohanka, Office of Naval Research, (703) 696-4309; alternative contact: Mr. Beau Brinckerhoff, NAVSEA, (202) 781-3659
- NAVSEA Corrosion Division—Mr. Dale Thomas (05M1), (202) 781-3671
- Corrosion Cost Studies at NSWCCD—Mr. William Needham, (301) 227-4961 (temporary phone number as of June 2004)
- Research and development projects to mitigate corrosion—Mr. Peter Kristiansen (NAVSEA SEA), (202) 781-3572.

Appendix B
Army Ground Vehicle Corrosion Cost Information

MAINTENANCE ORGANIZATION

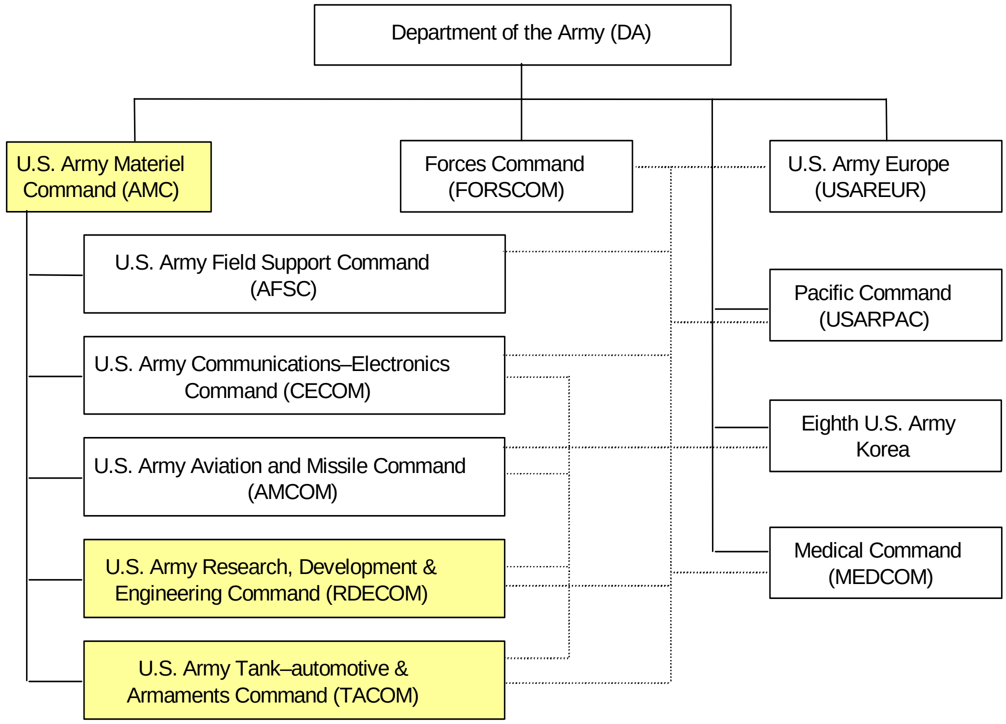
There are a variety of organizations involved in the planning and execution of maintenance on Army weapon systems. A number of reporting systems collect information on various aspects of maintenance, including a few specifically related to corrosion control. The U.S. Army Materiel Command (AMC) is the Army organization with the overall responsibility for procuring weapon systems and components, and for maintaining readiness of all Army equipment.

Although there are eight major subordinate commands within AMC, the maintenance of combat and tactical vehicles and associated systems is the primary responsibility of the U.S. Army Tank–automotive and Armaments Command (TACOM), with research, development, and engineering support provided by the newly formed Research, Development, and Engineering Command (RDECOM).[1] TACOM has the readiness responsibility for these systems, and uses a combination of organic maintenance depots, field activities, and commercial contractors to accomplish vehicle maintenance. In addition, intermediate-level maintenance is performed in the field, and at intermediate maintenance facilities by Army personnel or contractors, with failure data captured and reported back to TACOM.

The discipline of capturing and reporting corrosion data depends on the individual that diagnoses and makes the repair. As a result of the disbursed maintenance assignments, and the various levels of maintenance, there are a number of management information systems that gather failure and repair data and feed those data to the TACOM community. Because there are a number of different systems, there is also a wide variance in the methodology used in gathering those data. The major organizations and commands within the Army that manage and execute maintenance programs for ground systems are illustrated in Figure B-1.

[1] Newly formed provisional command that consolidated all AMC research, development, and engineering functions into a single organization that provides support to the various commodity commands.

Figure B-1. Army Command Structure



The above diagram does not depict all of the subordinate commands of DA and AMC, but it does reflect the major players who have the responsibility of using, maintaining, and repairing ground equipment. The dotted lines reflect an interface relationship of two commands to both the Army managers of ground equipment and the users of this equipment. In addition to RDECOM, which provides research, development, and engineering (RD&E) support to the commodity commands that manage the weapon systems, the newly formed U.S. Army Field Support Command (AFSC)[2] provides maintenance and supply technicians to the soldiers in the field in direct support of a particular commodity. For tracked and wheeled vehicles, AFSC is the intermediary between TACOM and the soldier in the field. AFSC also is in a position to identify corrosion-related problems and influence the proper identification and reporting of corrosion issues.

AMC has the overall responsibility for all weapon system management within the Army. Headquarters AMC (HQAMC) has established a Corrosion Prevention and Control (CPC) position to establish policy concerning corrosion management within the Army. The HQAMC point of contact is Mr. Hilton Mills, HQAMC G3 Corrosion Prevention and Control Lead, (703) 806-9840.

TACOM is the material readiness command for tracked and wheeled vehicles. The command is responsible for determining sources of repair and economical

[2] Newly formed provisional command that consolidated all field level, mobilization, and war reserve activities into a single command.

repair levels, and for administering and managing the execution of depot-level maintenance.

Army maintenance can generally be categorized as field-level or depot-level. Field-level maintenance includes organizational (on-equipment) tasks and a higher level of intermediate tasks than were previously performed under the traditional three-level maintenance concept. Depot-level maintenance still consists of all repairs beyond the capabilities of the field, including rebuild, overhaul, and extensive modification of equipment platforms, systems, and subsystems.

Field-Level Maintenance

Operating units and in-theater sustainment organizations perform field-level maintenance. These capabilities can be quite extensive and include remove-and-replace operations for components and subcomponents of line replacement units. Field maintenance is performed at more than a hundred different post, camp, and station locations throughout the world. The following are some of the major Army commands and their reporting field activities responsible for field maintenance:

- U.S. Army Europe (USAREUR), Germany
  - Kaiserslautern, Germany
  - Weisbaden, Germany
  - Vicenza, Italy
- U.S. Army Forces Command (FORSCOM), GA
  - Fort Bragg, NC
  - Fort Hood, TX
  - Fort Rucker, AL
  - Fort Lewis, WA
  - Fort Polk, LA
  - Fort Campbell, KY
- U.S. Army Pacific Command (USARPAC), HI
  - Schofield Barracks, HI
  - Fort Greely, AK
  - Fort Shafter, HI
  - Camp Zama, Japan

- Eighth U.S. Army, Korea
  - Camp Henry, Korea
  - Camp Humphreys, Korea
  - Camp Carroll, Korea
- U.S. Army Medical Command (MEDCOM), GA
  - Europe Region
  - Pacific Region
  - Great Plains Region
  - Southeast Region
  - Western Region
  - North Atlantic Region.

These sites are a fraction of the active sites that are users of the ground equipment that is subject to corrosion.

The Army uses the Standard Army Maintenance Information System (STAMIS) to gather and report maintenance data at the field or intermediate level. Information in STAMIS indicates that corrosion data are not captured except on wheeled vehicles through corrosion service centers. Currently, there are only two Army corrosion service centers, one at Schofield Barracks, HI, and the other at Fort Hood, TX. Corrosion data are taken periodically and analyzed to determine the rate of corrosion, and the cost of corrosion. This has been a manual effort by specially trained inspectors, and the data are fed into the Corrosion Database Management System (CORRDBMS), which is discussed later in this appendix. Because the collection of corrosion data is largely manual at these two sites, much of the information collected is only stored until it can be loaded into the database for analysis and use. TACOM has awarded a contract to upgrade the software for CORRDBMS and to automate the data collection and transfer interface to make the system more responsive and user friendly.

The points of contact for the Corrosion Service Centers are

- TACOM RD&E Center (TARDEC)—Mr. Karl Tebeau, (586) 574-5083, tebeauk@tacom.army.mil;
- TACOM RD& E Center, (RDECOM), Material and Environmental Office—Ali Baziari, (586) 574-8818, baziaria@tacom.army.mil;

- Armament RD&E Center (RDECOM)—Robert Zanowicz, (973) 724-5744, E-mail: zanowicz@pica.army.mil;
- Fort Hood, Texas—Chief, Force Modernization, Mr. Dale Clements, (254) 287-6539, dale.clements@hood.army.mil; and
- University of Hawaii, Manoa Honolulu, HI—Dr. Lloyd Hihara, (808) 956-2356, hihara@wiliki.eng.Hawaii.edu.

Depot-Level Maintenance

Depot maintenance is the most complex repair work performed by civilian artisans at fixed Army depots, other organic DoD depots, or commercial entities. There are two TACOM-managed depots that perform depot-level maintenance on wheeled and tracked weapon systems:

- Anniston Army Depot (ANAD), Anniston, AL
- Red River Army Depot (RRAD), Texarkana, TX.

Anniston has depot maintenance mission responsibility for all Army combat and tactical vehicles, with the exception of the following:

- Red River is responsible for depot maintenance of the Bradley family of fighting vehicles
- Tobyhanna Army Depot (TYAD) in Tobyhanna, PA, is responsible for satellite systems and communication shelters, many of which are mounted on tactical vehicles. TYAD is a depot under the command and control of CECOM.

The Standard Depot System (SDS) is used by the Army to manage depot maintenance workload. This system does not have a category for specifically identifying corrosion related problems and related workload. Recognizing that the Army depot maintenance is based on a fixed price concept, there are provisions in the system to identify specific scope of work changes that includes more than the normal expected level of corrosion. This often occurs on systems returning from Southwest Asia that have been exposed to salt water wash, especially fire control and other optic components. SDS includes Critical Maintenance Other Parts (CMOP), a module that can be used to identify the additional scope of work; but this module is seldom used. The normal means of identifying any corrosion above and beyond what would normally be expected on a system returned to a depot for overhaul is to notify the program manager (PM) for the system and request price renegotiation. These requests for renegotiation, with the stated scope of work change, is normally accomplished by phone, letter or e-mail, depending on the specific circumstances and the relationship with the PM.

Points of contact for Anniston Army Depot for the various type weapon systems managed and repaired there are

- Anniston Army Depot—Director for Missions, Plans, and Operations, Ms. Ester Griguhn, (256) 235-7523;
- Anniston Army Depot—PM for Abrams Tank, Mr. James Coley, (256) 741-5027;
- Anniston Army Depot—PM for M88 Vehicles, Mr. Ken Smith, (256) 235-6478; and
- Anniston Army Depot—PM for all tracked vehicles except the Abrams Tank, Mr. Charles Thompson, (256) 235-7568.

Points of contact for Red River Army Depot that are conversant with equipment corrosion related to the Bradley are

- Red River Army Depot—Assistant to Director for Maintenance, Mr. Chester Gordon, (903) 334-2104; and
- Red River Army Depot—Chief, Combat Division, Mr. John Moore, (903) 334-3835.

Corrosion management function for weapon systems at Anniston Army Depot resides in the Directorate of Engineering and Quality. The point of contact at Anniston Army Depot is the Director of Engineering and Quality, Mr. Tony Pollard, (256) 235-7071, tony.c.pollard@us.army.mil.

CORROSION CONTROL INITIATIVES

In the past few years, the Army has worked extensively in the area of corrosion, and has determined that corrosion loss within the Army exceeds $2 billion.[3] RDECOM and industry partners have undertaken a number of initiatives to identify high corrosion cost drivers and to initiate process changes that will reduce corrosion on Army weapon systems. Two primary initiatives are the establishment of corrosion service centers and the use of a centralized Army Corrosion Database Management System to collect, manage, and analyze corrosion data for wheeled vehicles.

[3] Corrosion Service Center status briefing, presented by Mr. Robert Zanowicz of the U.S. Army RD&E Center at the Army Corrosion Summit, Cocoa Beach, FL, 10 February 2004.

The Army researched the cause of the corrosion, and determined approximately one-third of its annual estimated $2 billion corrosion costs could be mitigated through simple treatment of the items. The Army established a prototype corrosion service center in Hawaii and, based on the results of the prototype site, recently activated one at Fort Hood.[4]

CORRDBMS is a statistical data management and analysis program that was originally developed for visual inspections of corrosion, damage and everyday wear of cars and trucks in the DoD tactical wheeled fleet. It includes all aspects of corrosion data: data collection, data reduction, and data analysis. By utilizing CORRBDMS, the Army can analyze results from the corrosion service centers and determine the most cost-effective corrective action.[5]

Although the particular application for the software by TACOM is tactical wheeled vehicles, the program is flexible enough to support several generic applications in other corrosion-related areas or maintenance in general. It can be adapted to any vehicle or piece of equipment that can be broken down into smaller components that can be replaced, repaired, or maintained.

TACOM recently awarded the Logistics and Environmental Support Services Corporation (LESCO) a contract to upgrade the CORRDBMS and provide interfaces with the corrosion service centers in the field to streamline the corrosion inspection and data gathering process, and to provide a direct link between the field and CORRDBMS.

A point of contact at TACOM RD&E Center, RDECOM, is Mr. Carl Handsy, (586) 574-7738, igor.carl.handsy@us.army.mil.

[4] Analysis of the need for corrosion centers at other sites at locations such as Fort Carson, Fort Sill, Okinawa, South Korea, and Germany is ongoing.

[5] This is a joint venture between the Army and industry.

Appendix C
Cost of Corrosion Study Elements for Naval Vessels

The total cost of corrosion within DoD is estimated to be between $10 billion and $20 billion annually.[1] Although the services have captured corrosion-related data in different forms for a number of years, until recently there was no standard method or structure for compiling this information. Because corrosion costs—and, therefore, opportunities for improvement—are high and the services face similar corrosion issues across common weapon systems platforms and facilities infrastructure, it is extremely beneficial to have a standard approach and structure for capturing corrosion costs and understanding what those costs are. The study elements in this appendix will help DoD better understand the corrosion costs that apply to naval vessels.

Definition of Corrosion

Corrosion is "the deterioration of a material or its properties due to a reaction of that material with its chemical environment." The maintenance costs of corrosion include activities, materials, equipment, and facilities used to prevent corrosion or to mitigate its effects. These costs include the lost value of the end item should it be unable to perform its mission due to corrosion and need to be scrapped or salvaged before the end of its expected life.[2]

Scope

This effort involves capturing tactically useful corrosion costs for naval vessels at all three levels of maintenance (organizational, intermediate, and depot) throughout the Navy. This includes all organic and contractor costs. Tactically useful cost elements are costs that change based on the corrosion source or environmental conditions.[3]

[1] Richard Kinzie and Ruth Jett, *DoD Cost of Corrosion*, 23 July 2003, p. 3.

[2] To calculate lost value, multiply the percentage of the average life lost by the original purchase price. For example, the lost value of a $1 million engine that should last 20 years but only lasts 15 years due to corrosion is (20−15)/20 × $1 million, or $250,000.

[3] In order to be tactically useful for decision-making, these cost elements need to be attributable exclusively to a single weapon system. In accounting terms, these may be viewed as variable costs.

These cost elements can be influenced by programmatic actions, such as technology insertions, a change in maintenance process or procedure, or the use of new materials. In the maintenance arena, tactically useful cost elements include

- direct man-hours,
- materials,
- scrap and disposal,
- corrosion related facilities and support equipment, and
- corrosion-related test equipment.

PREVENTIVE AND CORRECTIVE COSTS

Corrosion costs will be classified as either preventive or corrective.

- *Preventive costs* include steps taken to remove the causes of potential nonconformities or to make quality improvements. Preventive actions address potential problems, ones that haven't yet occurred. In general, the preventive action process can be thought of as a risk analysis process.
- *Corrective costs* are incurred when you to remove the causes of an existing nonconformity or to make quality improvements. Corrective actions address actual problems. In general, the corrective action process can be thought of as a problem-solving process.[4]

For the purposes of this study, each of the five tactically useful cost elements are classified as either corrective or preventive, as depicted in Table C-1.

Table C-1. Classification of Corrosion Cost Elements

Cost element	Corrective or preventive
Direct man-hours	Corrective or preventive
Materials	Corrective
Scrap and disposal	Corrective
Corrosion related facilities and support equipment	Preventive
Corrosion related test equipment	Preventive

[4] ISO 9000:2000 definition of corrective and preventive actions.

The classification of direct man-hours as a preventive or corrective cost is a judgment that must be made on a case-by-case basis. To ensure consistency, direct man-hours attributed to corrosion will be classified preventive or corrective based on the following convention:

- Hours spent using test equipment to check for the presence of corrosion are classified as a preventive cost.
- Hours spent at a facility built for the purpose of corrosion mitigation such as a wash facility are classified as a preventive cost.
- All other direct hours are classified as a corrective cost.

TASK LIST

The following tasks need to be accomplished as part of this study.

Task 1. Quantify the cost of corrosion for the five cost elements using FY04 data. If FY04 data are not available, FY03 data can be used with permission from the government.

- Use actual historical cost information as much as possible. (Use Table C-2 as a guide for data sources and points of contact.)
- Use statistically valid cost estimating techniques to fill data voids whenever possible.
- In costing corrosion work for which the actual labor costs are not known, document the normalized labor rate used to convert the labor hours into costs.

Task 2. Produce a summary report and a searchable cost database. These are the final products of the study.

- Structure naval vessel and support equipment data into six categories. Figure C-1 illustrates how corrosion costs are to be categorized.
    1. Carriers (e.g., CV-63, CVN-65, CVN-68)
    2. Amphibious (e.g., LHA-1, LPD-4, LSD-41)
    3. Surface warfare (e.g., DD-963, CGN-35)
    4. Submarines (e.g., SSN-21, SSN-772)
    5. Other watercraft (e.g., AEs, AFSs, MCMs)

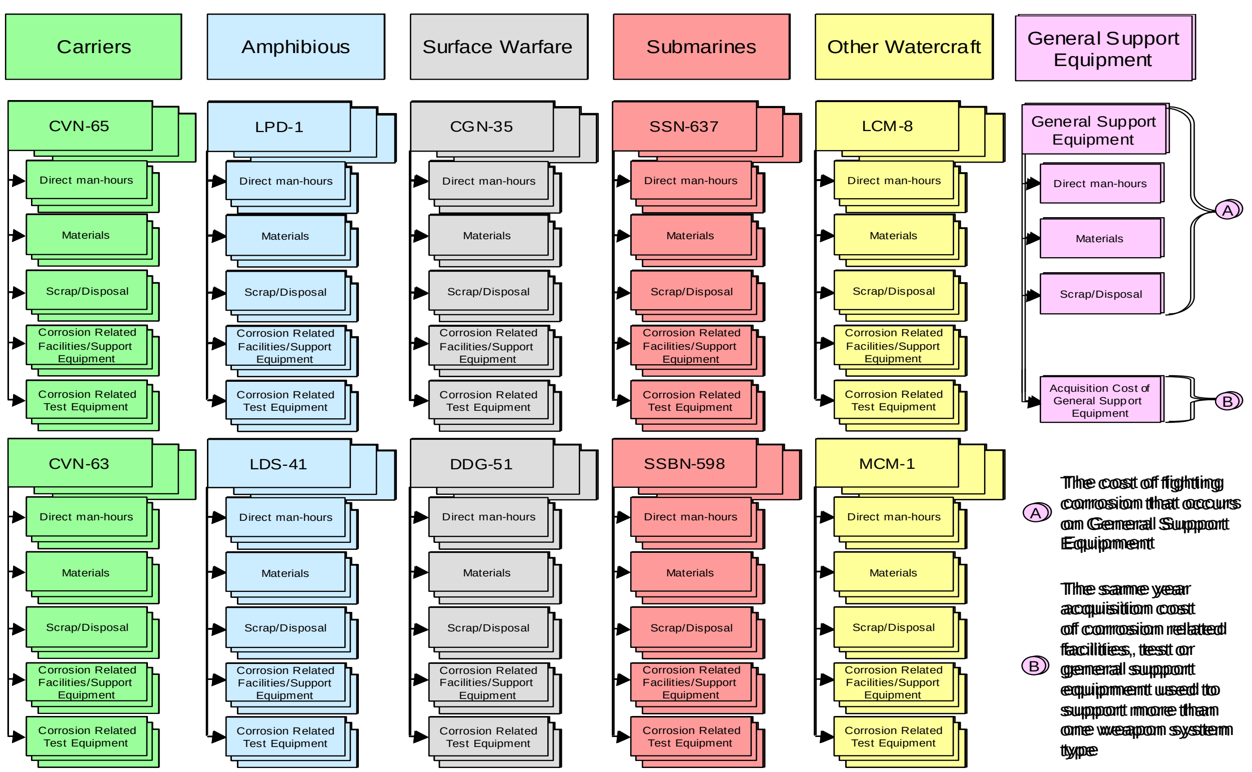
6. General support equipment—There are two categories of corrosion costs included in this grouping:

   a. Include the cost of preventing, detecting, or correcting corrosion on the equipment itself, or any other equipment used for the general maintenance support of naval vessels (see A in Figure C-1).

   b. For facilities, support equipment, and test equipment that supports more than one weapon system type and is acquired in the same year as the data being collected, identify the full acquisition costs as a cost of corrosion (see B in Figure C-1). If the cost information is not acquired in the same fiscal year as the data being collected, do not include these costs.

   Note: For corrosion-related facilities, support equipment, and test equipment that can only be attributed to a single weapon system (e.g., CVN, DDG), include only the acquisition costs if it is acquired in the fiscal year for which costs are being accumulated. This acquisition cost is included as a cost of corrosion for the appropriate weapon system. If the facility, support equipment or test equipment supports more than one weapon system, include the acquisition cost for the fiscal year for which costs are being accumulated in the General Support category of costs (outlined below).

Figure C-1. Corrosion Cost Structure



- For the first four categories of naval vessels, determine as much of the corrosion cost as possible for each vessel within that category.
- For the "other watercraft" category, determine the following if data systems do not support the collection of all cost elements (see Figure C-2):
  - Determine the number of each type of watercraft in active inventory.
  - Determine the total number of watercraft in active inventory by adding each of the subtotals.
  - Determine the actual corrosion costs for those watercraft types that comprise 80 percent of the total watercraft inventory. (This is the first part of the 80/20 rule.)
  - Use a statistically valid technique to extrapolate corrosion costs to the remaining 20 percent of watercraft. (This is the second part of the 80/20 rule.)

Figure C-2. Illustration of 80/20 Rule

Category										
Other Watercraft	Type	A	B	C	D	E	F	G	Total	80% of Total
	Number Active	12000	8000	5400	2500	1000	500	100	29500	23600
	Running Total	12000	20000	25400	27900	28900	29400	29500		

Compute Actual Costs for types A, B and C

Use a statistically valid extrapolation based on costs of type A, B and C to calculate costs of types D-G

- Develop a cost database that is searchable by each data element. The database will provide the flexibility for statistical analysis of each data element and subset of each data element.
- The database will contain the following data elements as a minimum:

  1. Performing activity

     a. Navy

     b. Army

     c. Air Force

     d. Marines

     e. Coast Guard

f. Contractor

g. Other

2. Nature of cost

a. Preventive

b. Corrective

3. Type of cost

a. Direct man-hours

i) Preventive

a) Inspection

b) Other

ii) Corrective

b. Materials—list type

c. Facilities and support equipment

d. Test equipment

e. Scrap and disposal

4. Actual cost incurred

5. Weapon system type

6. Weapon system unique identifier

7. Weapon system age

8. Weapon system hours of usage

9. Weapon subsystems using existing work breakdown structure (WBS) at each level of maintenance (organizational, intermediate, and depot) down to as detailed a level as current systems allow

10. Unit

11. Location.

- The database will likely be a compilation of individual work records. If each data element of the individual work record contains the same information except for the actual cost (element 4 above), the records can be combined into one record for ease of use.
- Provide the data elements and their characterizations (listed above) as a minimum requirement. For example, corrosion costs provide added value if they can be attributed to component- as well as subsystem-level detail.
- Present a study or research plan, including assumptions, within 30 days after the start of the project. This plan must be approved by the government.
- Give an interim status briefing 120 days after the start of the project.
- Deliver final products no later than 240 days after the start of the project.

Task 3. Document all data voids (i.e., any data element, weapon system, unit location, etc., without actual historical data) and propose a viable method to fill the data voids with historical data in the future.

RECOMMENDED FIRST STEPS

- Contact representatives in the Navy CPCIPT and SEA 04 and SEA 05. (Refer to Figure C-3 for Naval Sea Systems Command [NAVSEA] command structure and Table C-2 for point of contact information.) Research cost of corrosion background information and potential information sources as much as possible. (Use Table C-3 as a reference.)
- Contact representatives knowledgeable in the Material and Maintenance Management (3M) system, and determine the breadth of data availability. Refer to Table C-3 for originators of 3M data.
- Contact representatives knowledgeable of the Maintenance Requirements System (MRS), and determine the breadth of data availability. Refer to Table C-3 for originators of MRS data.
- Based on discussions with other points of contact, work from systems that have the most potential cost of corrosion information to the least.

Figure C-3. NAVSEA Command Structure

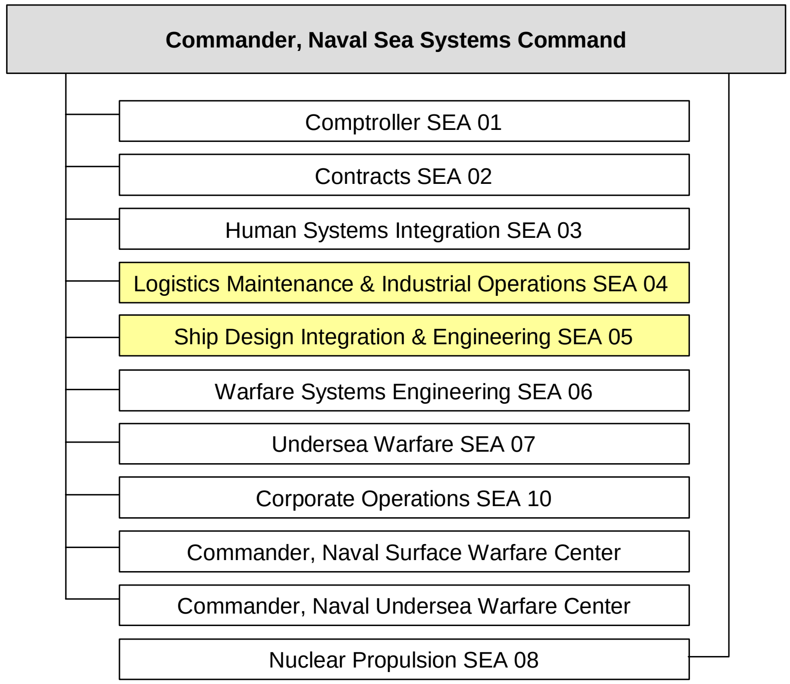


Table C-2. Navy Points of Contact for Corrosion Study

System or activity	Focus	Points of contact	Contact information	Comments
3M	O/I level	Phil Hans, NAVSEA 3M Program Manager Bill Casper, NAVSEALOGCEN 3M Program Manager	(202) 781-3372 (717) 605-5666	
MRS	Depot (ships)	Ken Jacobs, Fleet Maintenance Policy & Process (SEA 04) Rob Sears, NAVSEA Contractor Terry Wong, MRS Data Maintenance SUPSHIP	(202) 781-3382 (703) 460-1194 (757) 396-3796	
CPA	Depot (carriers)	Joel Korzun, Carrier Planning Activity	(757) 967-6123	
SUBMEPP	Depot (submarines)	Gary Jewell, SUBMEPP Willy Olmo, Commander, Submarine Force Atlantic Fleet	(207) 438-6144 (757) 836-1390	
NPPMIS	Coating	David Meikle	(202) 781-3667	No cost data
CCIMS	Carrier coating	Joel Korzun, Carrier Planning Activity	(757) 967-6123	No cost data
CCIMS	Submarine coating	Gary Jewell, SUBMEPP	(207) 438-6144	No cost data
BIRMIS	Boiler inspection/ repair	Terry Steck, Branch Head - code 622 Mike Gallagher, Analyst	(215) 897-7484 (215) 897-7314	No cost data No cost data
GT	Gas turbine	Terry Steck, Branch Head - code 622 Mike Gallagher, Analyst	(215) 897-7484 (215) 897-7314	No cost data No cost data
DSL	Diesel	Terry Steck, Branch Head - code 622 Mike Gallagher, Analyst	(215) 897-7484 (215) 897-7314	No cost data No cost data
VAMOSC	All levels and sources Navy wide system	Mike Carey, Navy Cost Analysis Division Mike Gallagher, Analyst	(730) 692-4901 (215) 897-7314	
No specific	General corrosion	Dr. Robert Pohanka, Navy representative on CPCIPT Beau Brinckerhoff, Navy representative on CPCIPT Dale Thomas, NAVSEA Corrosion Division (SEA 05) William Needham, Corrosion Cost Studies at NSWCCD Peter Kristiansen, Research and Development NAVSEA	(703) 696-4309 (202) 781-3659 (202) 781-3671 (301) 227-4961 (202) 781-3572	

Table C-3. Maintenance Levels and Information Systems for Naval Vessels

Maintenance level	Locations	Relevance	Information systems
Depot	Norfolk Naval Shipyard; Portsmouth, VA	Maintenance	MRS
	Portsmouth Naval Shipyard; Portsmouth, NH	Maintenance	SUBMEPP
	Pearl Harbor Shipyard and IMF; Pearl Harbor, HA	Maintenance	MRS
	Puget Sound Naval Shipyard and IMF; Bremerton, WA	Maintenance	MRS
	Naval Surface Warfare Center; Crane, IN	Maintenance	MRS
	Naval Undersea Warfare Center; Keyport, WA	Maintenance	MRS
	Supervisor of Shipbuilding (SUPSHIP)	Commercial contracts	
	Bath, ME	Commercial contracts	
	Pascagoula, MS	Commercial contracts	
	Ingleside, TX	Commercial contracts	
	Portsmouth, VA	Commercial contracts	
	Everett, WA	Commercial contracts	
	San Diego, CA	Commercial contracts	
	Newport News, VA	Commercial contracts	
	Groton, CT	Commercial contracts	
	Jacksonville, FL	Commercial contracts	
	New Orleans, LA	Commercial contracts	
	San Francisco, CA	Commercial contracts	
	Wallops Is., WA	Commercial contracts	
	Submarine Maintenance Engineering, Planning and	Planning and engineering	
	Procurement Activity (SUBMEPP); Portsmouth, NH	Planning and engineering	
	Naval Surface Warfare Center, West Bethesda, MD	Planning and engineering	
	Naval Sea Logistics Center; Mechanicsburg, PA	Planning and engineering	
	Carrier Planning Activity, Newport News, VA	Maintenance information	MRS
Intermediate	Pearl Harbor Shipyard and IMF; Pearl Harbor, HI	Maintenance	MRS
	Puget Sound Naval Shipyard and IMF; Bremerton, WA	Maintenance	MRS
	Shore Intermediate Maintenance Facility; Mayport, FL	Maintenance	3M
	Shore Intermediate Maintenance Facility; Portsmouth, VA	Maintenance	3M
	Shore Intermediate Maintenance Facility; Earl, Colts Neck, NJ	Maintenance	3M
	Shore Intermediate Maintenance Facility; Ingleside, TX	Maintenance	3M
	Shore Intermediate Maintenance Facility; Pascagoula, MS	Maintenance	3M
	Shore Intermediate Maintenance Facility, Everett, WA	Maintenance	3M
	Shore Intermediate Maintenance Facility; San Diego, CA	Maintenance	3M
	Ship Repair Facility Yokosuka, Japan	Maintenance	3M
	Trident Refit Facility Kings Bay, GA	Maintenance	3M
	Trident Refit Facility Bangor, WA	Maintenance	3M
	Naval Submarine Torpedo Facility Yorktown, VA	Maintenance	3M
	Naval Submarine Support Facility New London, CT	Maintenance	3M
	Naval Sea Logistics Center; Mechanicsburg, PA	Maintains Database	3M
Organizational	Potentially all vessels	Maintenance	3M

Table C-3. Maintenance Levels and Information Systems for Naval Vessels (Continued)

Maintenance level	Locations	Relevance	Information systems
General	Naval Surface Warfare Center, West Bethesda, MD	Weapons system–level costs	VAMOSC
	Naval Surface Warfare Center, Philadelphia, PA	Propulsion and power generation systems	BERMIS/GT/DSL
	Carrier Planning Activity, Newport News, VA	Coating information—carriers	CCIMC (CV/CVN)
	SUBMEPP, Portsmouth, NH	Coating information—submarines	CCIMC (CV/CVN)
	NAVSEA and NSWSCCD, Arlington, VA	Coating information—NAVSEA	NPPMIS

Appendix D
Cost of Corrosion Study Elements for Army Ground Systems

The total cost of corrosion within DoD is estimated to be between $10 billion and $20 billion annually.[1] Each service has captured corrosion-related data in different forms for a number of years, but until recently there was no standard method or structure for compiling this information. Because corrosion costs—and, therefore, opportunities for improvement—are high and the services face similar corrosion issues across common weapon systems platforms and facilities infrastructure, it is extremely beneficial to have a standard approach and structure for capturing corrosion costs and understanding what those costs are. The study elements in this appendix will help DoD better understand the corrosion costs that apply to the Army's ground systems.

DEFINITION OF CORROSION

Corrosion is "the deterioration of a material or its properties due to a reaction of that material with its chemical environment." The maintenance costs of corrosion include activities, materials, equipment, and facilities used to prevent corrosion or to mitigate its effects if it occurs. These costs include the lost value of the end item should it be unable to perform its mission due to corrosion and need to be scrapped or salvaged before the end of its expected life.[2]

SCOPE

This effort involves capturing tactically useful corrosion costs for Army ground vehicles at all three levels of maintenance (organizational, intermediate, and depot) throughout the Army, including all organic and contractor costs. Tactically useful cost elements are costs that change based on the corrosion source or environmental conditions.[3]

[1] Richard Kinzie and Ruth Jett, *DoD Cost of Corrosion*, 23 July 2003, p. 3.

[2] To calculate lost value, multiply the percentage of the average life lost by the original purchase price. For example, the lost value of a $1 million engine that should last 20 years but only lasts 15 years due to corrosion is (20−15)/20 × $1 million, or $250,000.

[3] In order to be tactically useful for decision-making, these cost elements need to be attributable exclusively to a single weapon system. In accounting terms, these may be viewed as variable costs.

These cost elements can be influenced by programmatic actions, such as technology insertions, a change in maintenance process or procedure, or the use of new materials. In the maintenance arena, tactically useful cost elements include

- direct man-hours,
- materials,
- scrap and disposal,
- corrosion related facilities and support equipment, and
- corrosion-related test equipment.

PREVENTIVE AND CORRECTIVE COSTS

Corrosion costs will be classified as either preventive or corrective.

- *Preventive costs* include steps taken to remove the causes of potential nonconformities or to make quality improvements. Preventive actions address potential problems, ones that haven't yet occurred. In general, the preventive action process can be thought of as a risk analysis process.

- *Corrective costs* are incurred when you to remove the causes of an existing nonconformity or to make quality improvements. Corrective actions address actual problems. In general, the corrective action process can be thought of as a problem-solving process.[4]

For the purposes of this study, each of the five tactically useful cost elements are classified as either corrective or preventive, as depicted in Table D-1.

Table D-1. Classification of Corrosion Cost Elements

Cost element	Corrective or preventive
Direct man-hours	Corrective or preventive
Materials	Corrective
Scrap and disposal	Corrective
Corrosion related facilities and support equipment	Preventive
Corrosion related test equipment	Preventive

[4] ISO 9000:2000 definition of corrective and preventive actions.

The classification of direct man-hours as a preventive or corrective cost is a judgment that must be made on a case-by-case basis. To ensure consistency, direct man-hours attributed to corrosion will be classified preventive or corrective based on the following convention:

- Hours spent using test equipment to check for the presence of corrosion are classified as a preventive cost.
- Hours spent at a facility built for the purpose of corrosion mitigation such as a wash facility are classified as a preventive cost.
- All other direct hours are classified as a corrective cost.

TASK LIST

The following tasks need to be accomplished as part of this study.

Task 1. Quantify the cost of corrosion for the five cost elements using FY04 data. If FY04 data is not available, FY03 data can be used with permission from the government.

- Use actual historical cost information as much as possible. (Use Table D-2 below as a guide for data sources and points of contact.)
- Use statistically valid cost estimating techniques to fill these voids for this study wherever possible.
- In costing corrosion work for which the actual labor costs are not known, document the normalized labor rate used to convert the labor hours into costs.

Task 2. Produce a summary report and a searchable cost database. These are the final products of the study.

- Structure Army ground vehicles and support equipment data into five categories. Figure D-1 illustrates how corrosion costs are to be categorized.

  1. Wheeled (examples are the LAV, ITV, HMMWV)
  2. Tracked (examples are the M-1 Tank, M-2 Bradley, M992)
  3. Towed (examples are the M198, M777, M58)
  4. Crew served weapons (e.g., M121 mortar, M138 GEMSS, M2 0.50 cal.)

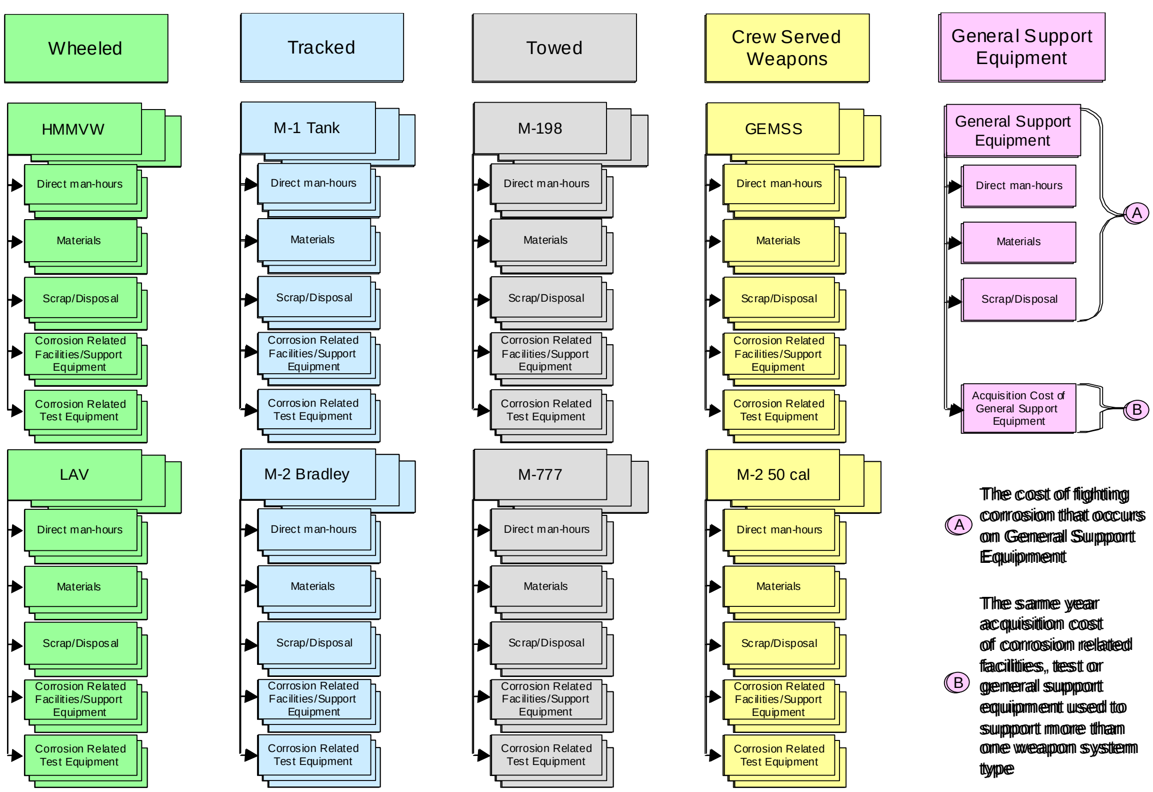
5. General support equipment—There will be two categories of corrosion costs included in this grouping:

    a. Include the cost of preventing, detecting, or correcting corrosion on this equipment itself, or any other equipment used for the general maintenance support of Army ground vehicles (see A in Figure D-1).

    b. For facilities, support equipment and test equipment that supports more than one weapon system type and is acquired in the same year as the data being collected, identify the full acquisition costs as a cost of corrosion (see B in Figure D-1). If the cost information is not acquired in the same fiscal year as the data being collected, do not include these costs.

Note: For corrosion related facilities, support equipment, and test equipment attributable exclusively to a single weapon system (e.g., CVN, DDG), include the acquisition costs only if acquired in the fiscal year for which costs are being accumulated. This acquisition cost will be included as a cost of corrosion for the appropriate weapon system. If the facility, support equipment or test equipment supports more than one weapon system, include the acquisition cost for the fiscal year for which costs are being accumulated in the "General Support" category of costs (outlined below).

Figure D-1. Corrosion Cost Structure



- For the first four categories of Army vehicles, determine the following if data systems do not support collecting all cost elements (refer to Figure D-2):

  - Determine the number of each type of vehicle in active inventory within each category.

  - Determine the total number of vehicles in active inventory by adding each of the subtotals within each category.

  - Determine the actual corrosion costs for the vehicle types that comprise 80 percent of the total vehicle inventory within each category. (This is the first part of the 80/20 rule.)

  - Use a statistically valid technique to extrapolate corrosion costs to the remaining 20 percent of vehicles within each category. (This is the second part of the 80/20 rule.)

Figure D-2. Illustration of 80/20 Rule

Category											
Wheeled	Type	A	B	C	D	E	F	G		Total	80% of Total
	Number Active	12000	8000	5400	2500	1000	500	100		29500	23600
	Running Total	12000	20000	25400	27900	28900	29400	29500			

Compute Actual Costs for types A, B and C

Use a statistically valid extrapolation based on costs of type A, B and C to calculate costs of types D-G

- Develop a cost database that is searchable by each data element. The database will provide the flexibility for statistical analysis of each data element and subset of each data element.

- The database will contain the following data elements as a minimum:

  1. Performing activity

     a. Army

     b. Navy

     c. Air Force

     d. Marines

     e. Coast Guard

     f. Contractor

     g. Other

2. Nature of cost

    a. Preventive

    b. Corrective

3. Type of cost

    a. Direct man-hours

        i) Preventive

            a) Inspection

            b) Other

        ii) Corrective

    b. Materials—list type

    c. Facilities and support equipment

    d. Test equipment

    e. Scrap and disposal

4. Actual cost incurred

5. Weapon system type

6. Weapon system unique identifier

7. Weapon system age

8. Weapon system hours of usage

9. Weapon subsystems using existing work breakdown structure (WBS) at each level of maintenance (organizational, intermediate, and depot) down to as detailed a level as current systems allow

10. Unit

11. Location.

- The database will likely be a compilation of individual work records. If each data element of the individual work record contains the same information except for the actual cost (element 4 above), the records can be combined into one record for ease of use.

- Provide the data elements and their characterizations (listed above) as a minimum requirement. For example, corrosion costs provide added value if they can be attributed to component- as well as subsystem-level detail.
- Present a study or research plan, including assumptions, within 30 days after the start of the project. This plan must be approved by the government.
- Give an interim status briefing 120 days after the start of the project.
- Final products to be delivered no later than 240 days after the start of the project.

Task 3. Document all data voids (i.e., any data element, weapon system, unit location, etc., without actual historical data) and propose a viable method to fill the data voids with historical data in the future.

RECOMMENDED FIRST STEPS

- Contact representatives in Army Materiel Command (AMC), Tactical Army Command (TACOM), and Research, Development, and Engineering Command (RDECOM). (Refer to Figure D-3 for the DA command structure and to Table D-2 for point of contact information.) Research cost of corrosion background information and potential information sources as much as possible. (Use Table D-3 as a reference.)
- Contact representatives knowledgeable of the corrosion service centers in Hawaii and Fort Hood. Determine the breadth of data availability.
- Contact representatives knowledgeable of Standard Depot System (SDS). Determine the breadth of data availability.
- Based on discussion with other points of contact, work from systems that have the most potential cost of corrosion information to the least.

Figure D-3. Department of the Army Command Structure

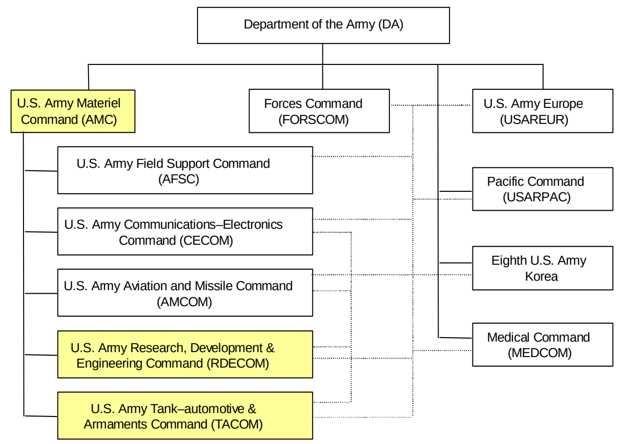


Table D-2. Army Points of Contact for Cost of Corrosion Study

System or activity	Focus	Point of contact	Phone	E-mail
AMC	Corrosion policy	Hilton Mills, HQAMC Corrosion Prevention Lead	703-806-9840	
Schofield Barracks	Corrosion service	Dr. Lloyd Hihara, University of Hawaii	808-956-2356	hihara@wiliki.eng.hawaii.edu
Hawaii	Center—O/I-level maintenance	LTC Robert Lehmen, G4 Commander	808-655-9313	
Fort Hood, TX	Corrosion service Center—O/I-level maintenance	Dale Clements, Chief - Force Modernization	254-287-6539	dale.clements@hood.army.mil
TACOM	Corrosion service Center—O/I-level maintenance	Karl Tebeau, TACOM RD&E Center Ali Baziari, TACOM RD&E Center	(586) 574-5083 (586) 574-8818	tebeauk@tacom.army.mil baziaria@tacom.army.mil
RDECOM	Corrosion service Center—O/I-level maintenance	Robert Zanowicz, Armament RD&E Center	973-724-5744	zanowicz@pica.army.mil
SDS Anniston	Depot—Plans/ops	Ester Griguhn, Director for Plans and Operations	(256) 235-7523	
SDS Anniston	Depot—Abrams tank	James Coley, Program Manager Abrams	(256) 741-5027	
SDS Anniston	Depot—M88 vehicles	Ken Smith, Program Manager M88	(256) 235-6478	
SDS Anniston	Depot—Tracked vehicles	Charles Thompson, Program Manager Tracked Vehicles	(256) 235-7568	
Red River	Depot—Bradley	Chester Gordon, Assistant Director of Maintenance	(903) 334-2104	
		John Moore, Chief, Combat Division	(903) 334-3835	
Anniston	Depot—Corrosion management	Tony Pollard, Director of Engineering and Quality	(256) 235-7071	tony.c.pollard@us.army.mil
CORRDMBS	O/I-level—Cost system	Carl Handsy, TACOM RD&E Center	(586) 574-7738	igor.carl.handsy@us.army.mil

Table D-3. Maintenance Levels and Information Systems for Army Ground Vehicles

Maintenance level	Locations	Relevance	Information systems
Depot level	Anniston Army Depot, Anniston, AL	Maintenance—wheeled and tracked	SDS
	Red River Army Depot, Texarkana, TX	Maintenance—wheeled and tracked	SDS
	Tobyhana Army Depot, Tobyhana, PA	Maintenance—communication systems	LMP
Field level	More than 100 different locations, such as:	Maintenance	STAMIS
	Fort Bragg, NC	Maintenance	STAMIS
	Fort Rucker, AL	Maintenance	STAMIS
	Vicenza, Italy	Maintenance	STAMIS
	Camp Zama, Japan	Maintenance	STAMIS
	Camp Henry, Korea	Maintenance	STAMIS
	Schofield Barracks, HI	Corrosion service center	CORRDBMS
	Fort Hood, TX	Corrosion service center	CORRDBMS
General	TACOM	Overall readiness responsibility	
	RDECOM	Corrosion control initiatives	
	AFSC	Provides maintenance technicians	

Appendix E
Abbreviations

BRAC	Base Realignment and Closure
CPCIPT	Corrosion Prevention and Control Integrated Product Team
GAO	Government Accountability Office
I.CAM	LMI’s infrastructure assessment model that can calculate the replacement value of infrastructure and facilities
ISO	International Organization for Standardization
NMC	non-mission capable
R&D	research and development
ROI	return on investment
WBS	work breakdown structure