Facilities and Infrastructure Corrosion Evaluation Study

Final Report

Response to
House Report 112-78
Accompanying
H.R. 1540, National Defense Authorization Act
for Fiscal Year 2012

The estimated cost of this report for the Department of Defense is approximately $1,143,000 in Fiscal Years 2012 - 2013. This was directed and funded above the presidents budget request. This includes $774,000 in expenses and $368,000 in DoD labor

July 2013

THE UNDER SECRETARY OF DEFENSE
3010 DEFENSE PENTAGON
WASHINGTON, DC 20301-3010

ACQUISITION, TECHNOLOGY AND LOGISTICS

The Honorable Carl Levin
Chairman
Committee on Armed Services
United States Senate
Washington, DC 20510

JUL 11 2013

Dear Mr. Chairman:

House Report No. 112-78, to accompany H.R.1540, the National Defense Authorization Act for Fiscal Year 2012, requests the Director, Corrosion Policy and Oversight, to submit to the congressional defense committees a report on the impact of corrosion on Department of Defense facilities and infrastructure. The enclosed facilities and infrastructure corrosion evaluation study identified key corrosion cost drivers, assessed a planned facility construction program, and examined documentation of maintenance and facility engineering processes in regards to corrosion. A representative sampling of facility type, Military Department, and facility age was also requested and is included in this report.

An identical letter has been sent to the Chairman of the House Committee on Armed Services.

Sincerely,

Frank Kendall

Enclosure:
As stated

cc:
The Honorable James M. Inhofe
Ranking Member

THE UNDER SECRETARY OF DEFENSE
3010 DEFENSE PENTAGON
WASHINGTON, DC 20301-3010

ACQUISITION, TECHNOLOGY AND LOGISTICS

JUL 1 1 2013

The Honorable Howard P. "Buck" McKeon
Chairman
Committee on Armed Services
U.S. House of Representatives
Washington, DC 20515

Dear Mr. Chairman:

House Report No. 112-78, to accompany H.R.1540, the National Defense Authorization Act for Fiscal Year 2012, requests the Director, Corrosion Policy and Oversight, to submit to the congressional defense committees a report on the impact of corrosion on Department of Defense facilities and infrastructure. The enclosed facilities and infrastructure corrosion evaluation study identified key corrosion cost drivers, assessed a planned facility construction program, and examined documentation of maintenance and facility engineering processes in regards to corrosion. A representative sampling of facility type, Military Department, and facility age was also requested and is included in this report.

An identical letter has been sent to the Chairman of the Senate Committee on Armed Services.

Sincerely,

Frank Kendall

Enclosure:
As stated

cc:
The Honorable Adam Smith
Ranking Member

Facilities and Infrastructure Corrosion Evaluation Study:
Final Report

JULY 2013

Executive Summary

The Department of Defense (DoD) manages a global real property portfolio of more than 555,000 facilities (buildings, structures, and linear structures) that are located across more than 5,000 sites worldwide that cover more than 28 million acres,[1] and are located in a broad range of environmental severity zones.[2] Policy makers and facilities management personnel address corrosion—and all its associated challenges—based on their respective operational requirements and resource availability.

This report presents the results of an evaluation of corrosion control challenges and findings of a small, but representative sample size of DoD installations. It represents the efforts of a team of subject matter experts who represent all branches of the military, industry, and academia.

The House Report accompanying H.R. 1540, the National Defense Authorization Act (NDAA) for Fiscal Year 2012 (H. Rept. 112-78, p. 293), requested the Director, Corrosion Policy and Oversight (D, CPO) conduct an evaluation of DoD facilities and infrastructure in corrosion matters. The committee states "…Department of Defense's $22.5 billion annual cost to address the impact of corrosion, the committee believes that there may be more cost-efficient opportunities for developing strategies for enhancing the sustainability of existing facilities as well as ensuring the integration of corrosion prevention and mitigation technologies into the buildup of future facilities." The DoD cost of corrosion equals the annual corrosion-related costs for both facilities and weapon systems. The cost of corrosion specific to facilities is estimated at $1.549 billion.[3]

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[1] Deputy Under Secretary of Defense for Installations and Environment, *Department of Defense Base Structure Report: Fiscal Year 2012 (A Summary of DoD's Real Property Inventory)*.

[2] The corrosion of metallic systems is a function of the product of the severity of the environment and time exposed to that environment. DoD established an Environmental Severity Index (ESI) derived from 10 years of observations of steel and aluminum alloy samples (or "coupons") left exposed to the elements at 130 military installations around the world.

[3] *The Annual Cost of Corrosion for the Department of Defense Facilities and Infrastructure: 2007–2008 Update*, LMI Report DL907T2, Eric F. Herzberg, Amelia Kelly, and Norman T. O'Meara, July 2010.

Congress requested an evaluation of key cost drivers, and strategies to reduce their impact; an assessment of a planned facility construction program; and the examination and documentation of maintenance and facility engineering processes. The report accompanying the FY2012 NDAA also requested the sampling of facilities be representative by facility type, military department, and facility age, and that the evaluation be completed within 300 days.

The facilities and infrastructure corrosion evaluation team found the military services are doing what they can in the areas of corrosion prevention and control (CPC); however, opportunities for improvement exist throughout DoD. The study team also noted that corrosion is often perceived as rust and oxidation of metals, rather than the more comprehensive definition in congressional language. Discussions of corrosion challenges became more fruitful after a clear definition of corrosion was understood. That lack of awareness did not diminish the compelling need of the facilities and infrastructure community to address materials degradation.

The following are among the findings of the facilities and infrastructure corrosion evaluation study:

- The study team identified key cost drivers using maintenance databases. These cost drivers were then confirmed during site visits. Policy makers and facilities maintainers can use these cost drivers as a reference point for addressing strategic enhancements in the sustainment of their installations.
- Installations located in severe environments (as measured by the Environmental Severity Index, or ESI) are subject to greater corrosion costs, as indicated by a recent cost-of-corrosion study.[4]
- After an extensive review of DoD facilities and infrastructure policies and criteria[5] in relation to corrosion mitigation, the study team compiled a list of guidance documents that specifically address CPC in the acquisition, development, and long-term management of DoD facilities and infrastructure. The study team noted considerable variability in the awareness and implementation of these CPC policies and guidance.
- Congress requested an assessment of a planned facility construction program. The D, CPO selected a construction program in an extreme ESI to assess CPC considerations during the planning, design, and construction phases. The study team noted that several design-phase requirements from that project included CPC material and installation criteria that were drawn from established DoD guidance and the experiences of the design community. The study team's assessment

[4] Ibid., LMI Report DL907T2.

[5] Policy and criteria are formal instruments to implement required actions for desired results. Policies provide direction on roles, responsibilities, liable actions and required documentation, and adherence to other prescribed standards. Criteria provide guidance on the technical application of construction standards, products, and maintenance of facilities/infrastructure. Key criteria include unified facilities guide specifications (UFGSs) unified facilities criteria (UFCs).

demonstrated that appropriate CPC planning and decisions made during the planning phase directly enhance a facility's life cycle—a good model of military construction from a CPC perspective.

- Maintenance and facility engineering processes in relation to CPC vary to some degree from installation to installation; however, most sites included in the study had similar CPC processes and practices, despite differences in mission and facility objectives.
- Resource constraints were a consistent concern at all sites included in the study. Compliance with required programs (such as Leadership in Energy and Environmental Design [LEED], Anti-Terrorism Force Protection, and the National Historic Preservation Act of 1966) reduces the funding an installation commander has available to eliminate or control the negative effects of corrosion.
- The study team noted several opportunities to improve the content and delivery of CPC training for the facilities and infrastructure community. Increased on-the-job and formal CPC training of facilities and infrastructure personnel would result in better corrosion-related decision making and help balance investments in preventive and corrective maintenance.
- Corrosion mitigation technology in the buildup of future facilities is purposefully explored by the military services, with some research and development funding provided by the D, CPO. The study team found that installations are reluctant to implement all but the most mature technologies, because of the inherent risk of failure and fear of losing scarce resources. These concerns can be alleviated somewhat; only proven and mature corrosion mitigating technologies are transitioned into the design and construction criteria.
- The process of transitioning new technology into criteria can be cumbersome and time consuming, resulting in large time lags before the new technology can be easily included in a contract.
- The study team believes better cross-installation communication would improve the dissemination and sharing of CPC best practices and accelerate the acceptance and implementation of new technologies.
- Effectiveness of contracting for facilities and infrastructure maintenance and repair varied across the services and installations. Where contracting personnel were familiar with facilities and infrastructure requirements, better CPC outcomes were achieved. Where contracting personnel were not familiar with facilities and infrastructure requirements, improved outcomes were not achieved. User involvement in the contracting process (from public works and engineering staff) improved the identification of CPC requirements and delivery of effective contracting solutions.

While not specific topics of this study, it should be noted that both Base Closure and Realignment and sequestration will have a bearing on corrosion impacts for DoD Facilities and Infrastructure. Closure of aging facilities will reduce associated corrosion-related sustainment costs. Sequestration will result in increasing levels of deferred maintenance and consequently result in higher levels of corrosion damage which will have negative impacts on cost and mission readiness.

Contents

Figures

Tables

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Chapter 1
Introduction

The Department of Defense (DoD) acquires, operates, and maintains a vast array of physical assets that range from vehicles, aircraft, ships, and other materiel to wharves, buildings, piping, pavement, and other stationary structures and infrastructure. All these assets are susceptible to corrosion.

Efforts to prevent and control the detrimental effects of corrosion (including repair and replacement) contribute significantly to the total ownership costs of DoD assets.[1] To control such costs, the Department must track corrosion's effects, assess the cost of those effects, and work to prevent corrosion of systems and structures. Congress directed the Director of the Office of Corrosion Policy and Oversight (D, CPO) to investigate strategies for enhancing the sustainability of existing facilities and ensuring the integration of corrosion prevention and mitigation technologies in future facilities and infrastructure (F&I).

CONGRESSIONAL REPORT LANGUAGE

The House Committee on Armed Services in their report (H. Rept. 112-78) to accompany H.R. 1540, the National Defense Authorization Act (NDAA) for Fiscal Year 2012, requested an evaluation of corrosion on DoD facilities and infrastructure. The House report states the following:

> Because the costs associated with facilities and infrastructure account for a significant portion of the Department of Defense's $22.5 billion annual cost to address the impact of corrosion, the committee believes that there may be more cost-efficient opportunities for developing strategies for enhancing the sustainability of existing facilities as well as for ensuring the integration of corrosion prevention and mitigation technologies into the buildup of future facilities. Therefore, the committee directs the Director of the Office of Corrosion Policy and Oversight (as designated by section 2228 of title 10, United States Code) to conduct a study of these costs and to submit the findings to the House Committee on Armed Services a report within 300 days after the date of enactment of this Act. The study should include the following:
>
> (1) Identify the key drivers of these costs and recommend strategies for reducing their impact.
>
> (2) Review a sampling of facilities that are representative of facility type, military department, and facility age.
>
> (3) An assessment of at least one planned facility construction program.

[1] DoD spends an estimated $22.5 billion annually to combat and prevent the effects of corrosion; facilities and infrastructure account for $1.904 billion of that estimated total.

> (4) Include, but not limited to, information obtained from site visits and the examination of program documentation including maintenance and facility engineering processes.
>
> The Director of Corrosion Policy and Oversight is further requested to consult with the Office of the Under Secretary of Defense for Acquisition, Technology, and Logistics to determine the appropriate level of access necessary to conduct an effective and comprehensive evaluation. Lastly, the committee directed the Comptroller General of the United States to provide an assessment to the congressional defense committees of the completeness of the evaluation within 60 days of the delivery of the Director's report to the congressional defense committees.

This report details the methods of the Facilities and Infrastructure Corrosion Evaluation (FICE) study team (including site visits and a sampling of representative facilities) and addresses the specific requirements, as outlined in H. Rept. 112-78:

- The identification of key drivers of corrosion-related costs
- An assessment of a planned facility construction program
- An identification of corrosion prevention and mitigation technologies that may be integrated into future facilities
- Service-specific facility engineering processes as they relate to corrosion prevention and mitigation.

CORROSION PREVENTION AND CONTROL: AN OVERVIEW

Basic system design, material selection, and production processes, along with the development and implementation of intrinsic corrosion prevention strategies, establish the risk of corrosion vulnerability of all defense assets. Effective tradeoffs during the stages of acquisition provide the best opportunity to select and apply design criteria that will prevent or mitigate future corrosion.

Corrosion vulnerability and the potential effects of corrosion need to be fully evaluated as part of program design and development activities. Inevitably, tradeoffs must be made through an open and transparent assessment of alternatives. (In other words, do the safety and readiness improvements merit the additional costs?) To that end, DoD and the military services have issued extensive guidance on the identification and management of corrosion and the design and construction as well as sustainment actions related to corrosion control.[2]

[2] Under Secretary of Defense for Acquisition, Technology and Logistics (USD[AT&L]), memorandum, *Corrosion Prevention and Control*, November 12, 2003.

DEFINITIONS

For the purpose of the FICE study, the following definitions apply:

- The term “corrosion” refers to the deterioration of a material or its properties due to a reaction of that material with its chemical environment.
- The terms “infrastructure” and “facility” include all buildings, structures, airfields, port facilities, surface and subterranean utility systems, heating and cooling systems, fuel tanks, pavements, and bridges.
- The term “acquisition” refers to the acquiring, by contract and with appropriated funds, of supplies or services (including construction) by and for the use of the federal government through purchase or lease, whether the supplies or services are already in existence or must be created, developed, demonstrated, and evaluated. The term “acquisition” throughout the report is in reference to facilities and infrastructure.

Corrosion most often is associated with rust and the oxidation of other metals; however, the congressional definition of corrosion (10 USC 2228) includes the deterioration of all materials through sun exposure, mold and mildew, wind, and other environmental elements.

According to the definition outlined by Congress, ultraviolet (UV) deterioration of electrical wire insulation is considered corrosion.

Pitting corrosion on a fuel tank, Guam.

Evaluation Approach

At the direction of the Under Secretary of Defense for Acquisition, Technology and Logistics (USD[AT&L]),[3] the D, CPO assembled a study team to evaluate the costs, technology, and sustainment issues associated with the corrosion of DoD facilities and infrastructure. The study team included representatives from appropriate stakeholder organizations and experts in the fields of F&I and corrosion. Appendix A lists the members and affiliations of the FICE study team.

The study team reviewed program documents and developed questionnaires to send to facility managers to elicit information. The questionnaires and interviews were standardized to maintain consistency in the information being gathered. The team then visited 15 locations around the globe and interviewed by teleconference representatives from 15 other installations. Two laboratory-level commands and the Naval Facilities Command (NAVFAC) Criteria Office were also sent the questionnaire and were interviewed.

The FICE study team then analyzed the information drawn from the questionnaire responses and interviews for the causes of corrosion, lessons learned in the mitigation and prevention of corrosion, and examples of the application of best or accepted practices.

Policy and Requirements

The FICE study team's evaluation was founded on a thorough review of headquarters-level requirements and policies associated with the acquisition and sustainment of facilities. The team also identified areas for assessing acquisitions with respect to technology identification and validation, requirements development, project acquisition, and sustainment. Then, during site visits and phone interviews, the team reviewed the flow, management application, and field-level execution of these corrosion-related requirements and policies and assessed how well the current policy, guidance, and processes were being implemented at each organization or site.

Appendix B presents a comprehensive list of DoD and service-level corrosion prevention and control–related policies and guidance.

Questionnaire

Questionnaires were sent to representatives at each site in advance of the study team's visit or phone interview. The FICE study team also provided a preliminary brief to each site's point of contact and staff to ensure the correct interpretation and guidance was provided when responding to the questionnaire.

[3] USD(AT&L) memorandum, *Corrosion Evaluation with Respect to Facilities and Infrastructure*, April 25, 2012.

The study team asked respondents to answer questions as best they could, and return the completed questionnaire before the study team's scheduled arrival or interview. Gaps in requested information or deficient responses were addressed on site or during conference calls to maximize productive information exchange.

Site Selection

The team selected 30 locations (including operating bases, training bases, joint operating bases, depots, and regional commands), with representation across the services. The size and missions of the selected installations vary, but all are "major installations" that host numerous tenants. The 30 selected locations served as the sample for the study. The team visited program offices, military service installations, and headquarters offices. The team's site visits included briefings and discussions with engineers, maintainers, researchers, and managers, followed by base tours to examine site specific corrosion issues and to demonstrate F&I corrosion issues and best practices, as appropriate.

Population of Interest

As a first step to arrive at the final group of 30 locations, the team began with the 5,211 DoD sites listed in the Facilities Asset Database, or FAD (also known as the Base Structure Report).[4] The number of sites named in the FAD presented a challenge to the team as it strived to select from this large population a representative set of installation locations for the study. The database includes thousands of sites inappropriate for the study, such as standalone National Guard armories, reserve centers, and parcels of raw land. The team screened the incongruous site records out of the population of interest. For example, the Army Reserve Center (ARC) at Fort A.P. Hill was referred to as ARC Hill, even though it was a tenant to an already large host location. Because the team's goal was to identify only major sites (the selected host location) to represent all tenants, it was necessary to identify Fort A.P. Hill as the host organization. To normalize this list and prevent confusion or the possible skewing of data, the team used a common naming convention to appropriately identify installations as singular locations.

In this way, the FICE study team was able to reduce the 5,211 sites to a list of 772 installations.

Environmental Severity Index

The corrosion of metallic systems is a function of the product of the severity of the environment and time exposed to that environment. DoD has established an Environmental Severity Index (ESI) derived from 10 years of observations of steel and aluminum alloy bare metal samples (or "coupons") left exposed to the

[4] Office of the Deputy Under Secretary of Defense (Installations and Environment), *Base Structure Report Fiscal Year 2012 Baseline*: *A Summary of DoD's Real Property Inventory*, http://www.acq.osd.mil/ie/download/bsr/BSR%202012%20Baselinev2.pdf (accessed December 24, 2012).

elements at 130 military installations around the world.[5] The FICE study team used the ESI zones for steel coupons, because steel is most similar to the materials present in F&I (as opposed to aluminum alloys, which are more germane to studies of weapon systems degradation).

ESI zones are identified by a relative severity scale; lower numbers represent lower rates of material degradation, and higher numbers zones indicate higher levels of material degradation. Twenty ESI zones were established in this way, and each of the 130 military installations with a coupon test site was assigned to one of the 20 ESI zones.[6]

For DoD installations without an ESI coupon collection, the predictors for environmental influence on corrosion have been the standards for time of wetness (TOW) and salinity (S).[7] The TOW is the number of hours a location experiences greater than 32°F and greater than 80 percent humidity. The TOW measure is divided into five gradients, with 1 being the lowest and 5 the highest. The salinity measure is simply whether the center of the majority of the installation lies within 1 mile of seawater. It is a binary, yes or no measure. Combining the five TOW gradients with the two possible salinity measures (for example, 3/Yes) yields 10 possible TOW/S categories.

All DoD installations are assigned to a TOW/S category. A subset of the installations, those with test coupon sites, also had an ESI zone. By correlating these two measures for installations that had both values, the FICE study team was able to create an index that relates ESI to TOW/S. The study team then used this index to assign each installation that did not have coupon measurement station to an ESI zone.[8] The relative frequency of installations assigned to each of the ESI zones by this method is shown in Figure 1-1.

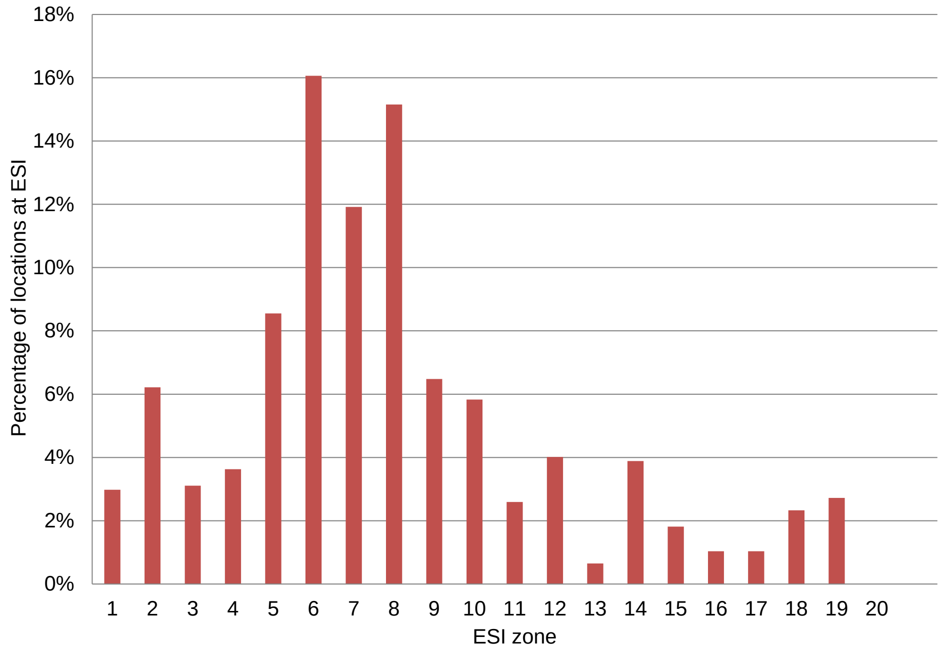
[5] The majority of the coupons are mounted above ground, with a small number placed where they will be submerged by ocean water at high tide.

[6] It is important to understand that the term ESI refers only to the severity and corrosion on metallic systems as a result of exposure to the natural outdoor atmospheric environment. For example, materials buried in soil (such as pipelines) or immersed in liquids (such as seawater) are excluded from the ESI concept.

[7] Time of wetness and salinity are two factors that greatly influence corrosion rates, as documented in International Organization of Standardization (ISO) 9223:2012, "Corrosion of Metals and Alloys: Classification of Corrosivity of Atmospheres—Classification, Determination, and Estimation."

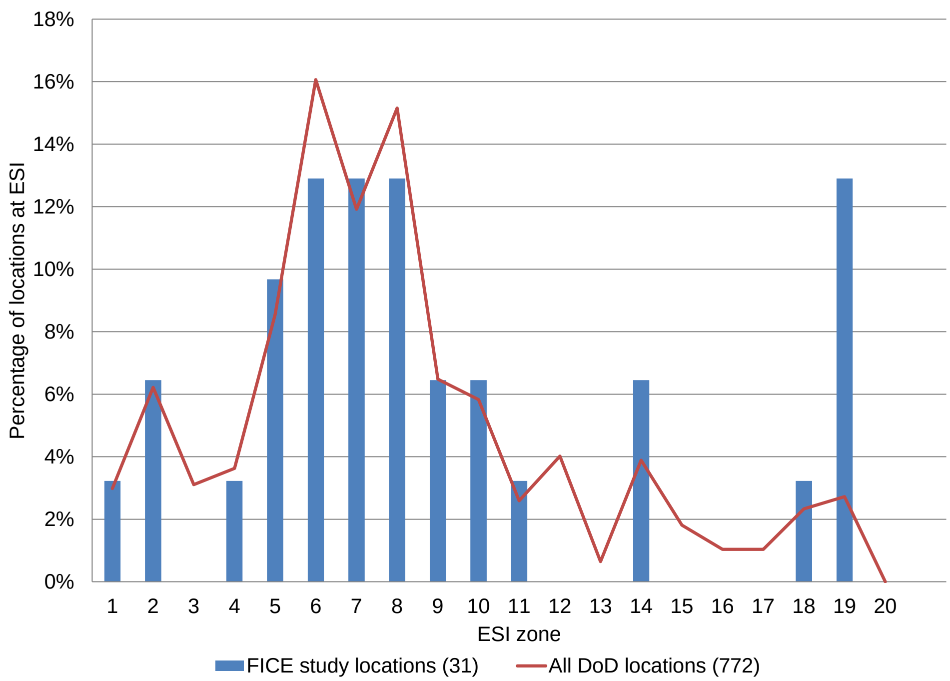
[8] If there were multiple sites within an overseas location or U.S. state with the same TOW/S but with different ESIs, the study team assigned the highest ESI assessed for that location.

Figure 1-1. Percentage of DoD Installations by ESI Zone



The team selected DoD sites to emulate the distribution of all DoD installations by ESI zone (see Figure 1-2).

Figure 1-2. Comparison of DoD Distribution and Study Sample Size by ESI Zone



The high percentage of ESI zone 19 locations selected for evaluation is a consequence of two factors unique to the FICE study. First, the study team focused on a greater selection of DoD installations in the highest ESI zone to determine the effectiveness of DoD and military service policies, regional management, and local execution of those policies or processes. Second, the team had an opportunity to visit multiple installation locations during a single site visit (all military services are represented in seven different installations within the 600 square miles of Oahu, Hawaii).

Facility Class and Age

The selection of the 30 installations also accounted for the types of facilities established at each location and considered the age of those facilities. Following DoD Instruction (DoDI) 4165.03, *DoD Real Property Categorization*, the study team classified all facilities at the 1-digit facility class for appropriate sampling (see Table 1-1). Each class of facility is associated with the 30 installations by this 1-digit code with the exception of facility class 9, raw land.[9]

Table 1-1. DoD Facility Classification

1-digit code	DoD facility class
1	Operational and training facility
2	Maintenance and production facility
3	Research, development, test, and evaluation (RDT&E) facility
4	Supply facility
5	Hospital or medical facility
6	Administrative facility
7	Housing and community facility
8	Utilities and ground improvements facility
9	Raw land

Facility age is included in the study; however, the placement of an age on a specific facility type is difficult. Because all installations have continual sustainment, restoration, and modernization (SRM) plans, an installation may have any number of facility types and infrastructure that span a wide spectrum of ages. For example, a section of failed piping on Marine Corps base (MCB) Quantico was recently repaired and replaced. This section of pipe was wooden, indicating it predates the official establishment of MCB Quantico. Therefore, the assignment of a single age to MCB Quantico—or any site—would be inaccurate at best.

Rather than attempt to capture the age of F&I, the FICE study team used the year the installation was established. This demonstrates the level of F&I maintenance and better illustrates the challenges of aging F&I. No installation surveyed as part of the FICE study was less than 50 years old, and half of the sample installations were established in preparation for or response to World War II.

[9] Raw land is considered outside the scope of the study.

FINAL SAMPLE

The final 30 installations selected for study are listed in Table 1-2.

Table 1-2. Installations Visited or Interviewed

Service	Installation	Facility classes (1-digit)	Date of installation establishment	Assigned ESI zone
Army	Fort A.P. Hill, Virginia	1, 6, 7	1941	8
	Fort Detrick, Maryland	1–8	1931	7
	Fort Hood, Texas	1–8	1942	6
	Fort Leonard Wood, Missouri	1–8	1941	5
	Fort Sill, Oklahoma	1–8	1869	5
	Pohakuloa Training Area, Hawaii	1–8	1955	2
	Schofield Barracks, Hawaii	1–8	1909	19
	Tobyhanna Army Depot, Pennsylvania	1–8	1912	6
Navy	NAS Corpus Christi, Texas	1–8	1941	19
	NAS Crane, Indiana	1–8	1941	8
	NAS Meridian, Mississippi	1–8	1961	5
	NAS North Island, California	1–8	1917	14
	Norfolk Naval Shipyard, Virginia	1–8	1767	11
	Puget Sound Naval Shipyard, Washington	1–8	1891	18
Marine Corps	MCAS Miramar, California	1–8	1945	6
	MCAS Yuma, Arizona	1–8	1928	1
	MCB Camp Pendleton, California	1–8	1942	14
	MCB Kaneohe Bay, Hawaii	1–8	1918	19
	MCB Quantico, Virginia	1–8	1917	8
	MCLB Albany, Georgia	1–8	1952	8
Air Force	Barksdale AFB, Louisiana	1–8	1933	9
	Little Rock AFB, Arkansas	1–8	1953	7
	Robins AFB, Georgia	1–8	1941	10
	Whiteman AFB, Missouri	1–8	1942	7
	Wright-Patterson AFB, Ohio	1–8	1917	9
Joint	JB Andrews (USAF), Maryland	1–8	1942	7
	JB Elmendorf-Richardson (USAF), Alaska	1–8	1940	2
	Joint Region Marianas (USN), Guam	1–8	1944	19
	JB Pearl Harbor/Hickam (USN), Hawaii	1–8	1908/1935	19
	JB San Antonio (USAF), Texas	1–8	1941	6

Notes: Installations highlighted in yellow were included in site visits; all others were interviewed by teleconference.

AFB = Air Force base; JB = joint base; MCAS = Marine Corps air station; MCB = Marine Corps base; MCLB = Marine Corps logistics base; NAS = naval air station; USAF = U.S. Air Force; USN = U.S. Navy.

STRUCTURE OF THE REPORT

The remainder of the report is organized as follows:

- Chapter 2 identifies key actors in the development and implementation of corrosion policies and summarizes the FICE study team's review of headquarters-level policies and processes associated with the acquisition and sustainment of facilities.
- Chapter 3 describes the key drivers of corrosion-related costs identified by the FICE study team.
- Chapter 4 presents the team's findings related to the military construction (MILCON) program.
- Chapter 5 provides an overview of corrosion prevention and mitigation technologies that have been integrated into the buildup of facilities and those that are under current consideration into future facilities.
- Chapter 6 presents military service–specific facility engineering processes and responses to study team questionnaires as they relate to corrosion prevention and mitigation.
- Chapter 7 summarizes the FICE study team's major findings and outlines the study team's conclusions related to the specific requirements, as outlined in H. Rept. 112-78.

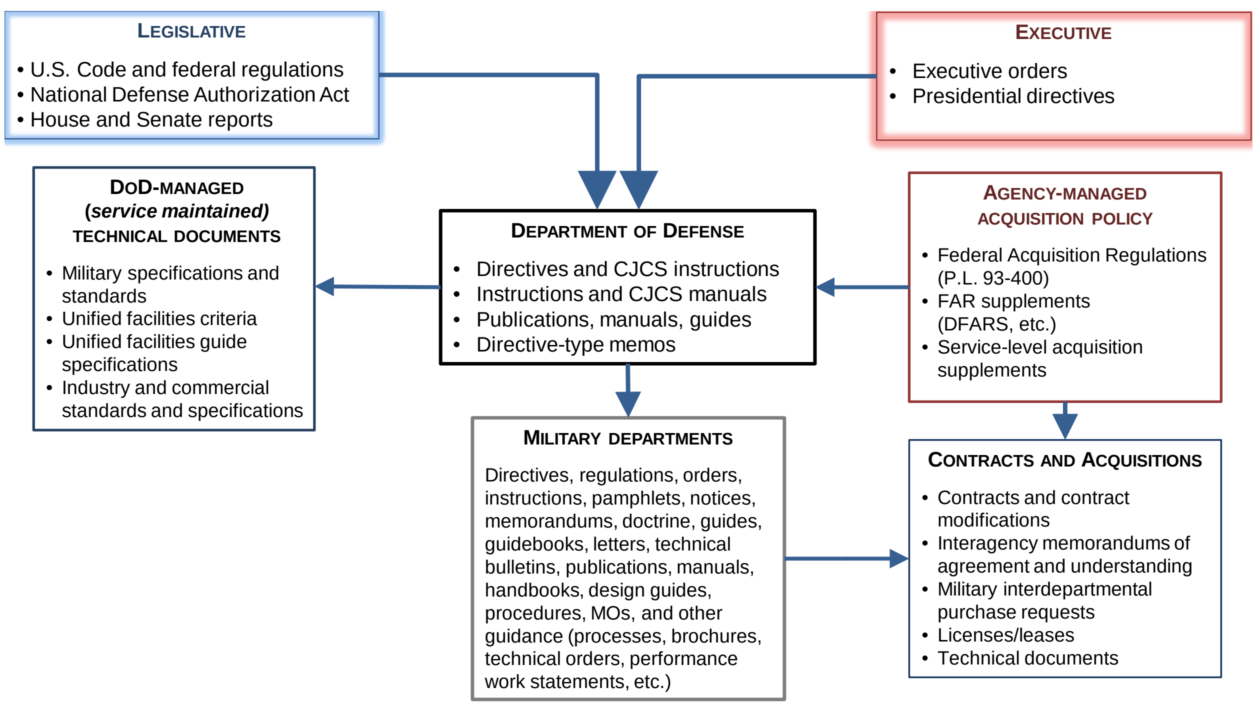
A series of appendixes provide supporting details, and an annex presents the unmodified comments of the Army, Navy, and Air Force regarding the draft of this report (which was released for comment in April 2013).

Chapter 2
Organizational Policy and Acquisition Process Overview

Facility and infrastructure acquisition management and associated actions are shaped by the nature of an installation's mission (which includes the requirements placed on it by weapon systems and other operational demands), the policies that dictate management, constraints in budget, and the political environment. This chapter briefly explains the roles of F&I organizations, how corrosion mitigation efforts factor into the strategies of those organizations, the policies that dictate the processes F&I managers follow, and the requirements they must fulfill.

Figure 2-1 shows the relationship of the various policies and guidance within the Department of Defense. The laws and executive orders guide DoD and the military departments; DoD translates legislative and executive direction into guidance and policy that enable compliance with the law.

Figure 2-1. DoD Policy Hierarchy Relationships



Note: CJCS = Chairman of the Joint Chiefs of Staff; DFARS = Defense Federal Acquisition Regulations Supplement; FAR = Federal Acquisition Regulations; MO = method of operation; P.L. = public law.

Another way to consider the policy process is to consider that the Acquisition support function (e.g., FAR/DFARS, technical documents, and contracts) exists to achieve the DoD's goals. The balance of the guidance and policy applies to the day-to-day business of the department and is intended to help DoD achieve operational and administrative functionality.

DoD Organizations with Corrosion-Related F&I Responsibilities

Within the Department of Defense, the Director of Corrosion Policy and Oversight (assigned by the Under Secretary of Defense for Acquisitions, Logistics and Technology)[1] and the Deputy Under Secretary of Defense for Installations and Environment (DUSD[I&E]) are responsible for policy and guidance with respect to controlling and mitigating the effects of corrosion on DoD facilities and infrastructure. The corrosion control and prevention executives (CCPEs)[2] from each military service ensure corrosion prevention and control (CPC) is maintained in the department's policy and guidance for system acquisition and production, RDT&E programs, equipment standardization programs, logistics research and development (R&D) activities, logistics support analysis, and military infrastructure design, construction and maintenance.

Director, Corrosion Policy and Oversight

The position and office of D, CPO was established by 10 USC 2228. The civilian director is responsible for developing long-term strategies to reduce corrosion and its effects on military equipment and infrastructure of the Department of Defense. Section 2228 lists the duties of the D,CPO, which include overseeing and coordinating efforts throughout DoD to

- prevent and mitigate the corrosion of military equipment and infrastructure,
- develop and recommend policy guidance,
- review programs and funding levels during the annual internal DoD budget review process,
- provide oversight and coordination of the corrosion prevention and mitigation efforts within DoD, and
- monitor acquisition practices.

[1] The position and office of Director of Corrosion Policy and Oversight was established through 10 USC 2228, December 2, 2002.

[2] Section 903 of the Duncan Hunter NDAA for FY2009 requires each military department designate a corrosion control and prevention executive.

Section 2228 assigns the D, CPO the responsibility for developing and implementing long-term strategies to reduce corrosion's effect on military equipment and infrastructure, ensure relevant training is in place, and interact with the corrosion prevention industry and others.

D, CPO has working integrated project teams (WIPTs) that are actively engage in the following areas: training and certification, policy, F&I, science and technology, metrics, impact, sustainment, outreach and communication, and the specifications, standards, and qualifications process. These WIPTs are supported by technical experts from DoD, the military services, academia, and industry.

The D, CPO is the DoD lead for developing a comprehensive program to address corrosion prevention and control, while the military departments maintain their respective control of funding and individual policies. D, CPO is continually working to focus attention on facilities and infrastructure, ensuring the policies in place are current and correctly interact with the DoD corrosion prevention and control program.

The D, CPO actively coordinates with other parts of the Office of the Secretary of Defense (OSD) and the military services when assessing and expanding the coverage of CPC in other policy and guidance documents.

Deputy Under Secretary of Defense (Installations and Environment)

Environmental management, facility investment and housing management, energy privatization, and environmental readiness and safety are responsibilities of the DUSD(I&E).

DUSD(I&E) is responsible for MILCON policy and administration, facility SRM programs, and the *Whole Building Design Guide* (WBDG, www.wbdg.org), which hosts the criteria documents used by the military services for F&I design and construction. Included in the WBDG are the criteria that address corrosion prevention and control.

DUSD(I&E) actively participates in the Corrosion Prevention and Control Integrated Product Team (CPC IPT).

Corrosion Control and Prevention Executives

The CCPEs ensure corrosion control and prevention are adequately addressed in the department's policy and guidance for system acquisition and production, RDT&E programs, equipment standardization programs, logistics R&D activities, logistics support analysis, and military infrastructure design, construction, and maintenance. Each CCPE (Army, Department of the Navy, and Air Force) is involved in D, CPO committees, including the Corrosion Board of Directors (CBOD), the CPC IPT, and the Corrosion Policy, Procedures, Processes, and

Oversight Working Integrated Product Team (C3PO WIPT). In addition, the CCPEs frequently collaborate with the D, CPO and his staff.

The Army CCPE serves under the Assistant Secretary of the Army for Acquisition, Logistics and Technology and serves as the Deputy Assistant Secretary of the Army (Acquisition Policy and Logistics), or DASA(APL). The Department of the Navy (DoN) CCPE is located within the Chief Systems Engineer's office and reports, through the Deputy Assistant Secretary of the Navy (Research, Development, Test and Evaluation), to the Assistant Secretary of the Navy (Research, Development and Acquisition). The Air Force CCPE serves under the Assistant Secretary of the Air Force (Acquisition) and works directly for the Deputy Assistant Secretary (Acquisition Integration).

CCPEs collect, evaluate, and prioritize D, CPO F&I technology demonstration projects. The CCPEs also oversee recommended F&I policy and guidance changes that are presented to the CBOD and C3PO WIPT.

Joint Bases

The joint basing program represents DoD's efforts to optimize the delivery of installation support at installations (as a result of Base Realignment and Closure, 2005) that are in close proximity or share a boundary. Joint bases are established using both common guidance and specific memoranda of agreement.

DoD activities provide base operating support to other DoD activities when it is in the best interest of the U.S. government and when the supplying activity has the capabilities to provide the needed support without jeopardizing other assigned missions.[3] The quality of support services provided to other DoD activities must be equivalent to the quality of support the supplier furnishes to its own mission. DoD activities may request support from other DoD activities when in-house capabilities do not exist, or when support can be obtained more efficiently or effectively from other DoD capabilities.[4]

Inter-service and intra-governmental support is reimbursable to the extent the specified support increases the supplier's direct costs. Costs associated with common use infrastructure are non-reimbursable, except for support provided solely for the benefit of one or more tenants. Reimbursement for Working Capital Fund mission products and services is based on the approved stabilized rate. Other incidental support is reimbursed based on direct cost measurable and is directly attributable to the support receiver (incremental direct cost).[5]

[3] DoDI 4000.19, *Interservice and Intragovernmental Support*, August 9, 1995.

[4] DoDI 4000.19, Paragraph 4.3.

[5] DoDI 4000.19, Paragraph 4.6.

Engineering Senior Executive Panel

The Engineering Senior Executive Panel (ESEP) consists of and is led by the senior executive engineers from DUSD(I&E), U.S. Army Corps of Engineers (USACE), NAVFAC, and Air Force Civil Engineer Center (AFCEC). Additional membership includes Marine Corps Installation Command (MCICOM), Assistant Chief of Staff for Installation Management (ACSIM), and other members, depending on the issues under consideration.

The ESEP provides oversight and approval for criteria and specification actions associated with the *Whole Building Design Guide*. According to its charter the ESEP is to promote greater use of tri-service engineering and design criteria, with a preference for the use of non-government standards. The ESEP establishes unified design guidance policy, charters the Tri-Service Design Guidance Coordinating Panel, provides oversight of the unified design guidance process, resolves issues that may impede unified design guidance, and acts as the resource and budget proponent for unified design guidance.

The ESEP and the National Institute of Building Sciences (NIBS)[6] have worked to consolidate and standardize the use of unified criteria documents. Several criteria documents in the WBDG address corrosion and structural deterioration issues. The WBDG represents an enormous knowledge-based sharing platform that engages all of the military services and other defense and federal agencies. Technologies are reviewed and addressed via a formal process to ensure due diligence. This includes CPC technologies submitted via government or private sector resources.

Policy and Guidance Overview

The Department of Defense has in place extensive policy and guidance (as illustrated in Figure 2-1) to facilitate effective management of the many complex areas required to provide for the national defense. Decisions made in F&I affect the readiness and availability of equipment and operations. To ensure the effective support of weapon systems, facilities must be in sync with the requirement. For example, a dry dock facility must be sized to the ship it supports and must be available and functioning when ship availability occurs. Corrosion-related shortfalls affect F&I readiness and the ability of the facility to support the mission.

Included in the remainder of this chapter (and in Appendix B) are policies that establish the overarching environment that serves as the basis for identifying which corrosion prevention and control is required and achieved. The CPC function is an essential part of the F&I program in support of the readiness mission of DoD.

[6] We discuss the NIBS, a congressionally authorized institution, in greater detail later in this chapter.

For CPC to be effectively controlled and accomplished, overarching policy and guidance must be in place in the form of acquisition regulations, directives, instructions, memoranda, and criteria that address essential areas, such as military construction, repair, and maintenance programs. Weapon systems and F&I acquisition systems must be functioning well and in sync with each other to provide for a seamless delivery system, as established by DoD Directive (DoDD) 5000.01 and DoDI 5000.02.

The following are important DoD policies and guidance that ultimately ensure the CPC F&I program can be managed:[7]

- DoDD 5000.01, *The Defense Acquisition System*, May 12, 2003
- DoDD 4270.5, *Military Construction*, February 12, 2005
- DoDI 5000.02, *Operation of the Defense Acquisition System*, December 8, 2008
- DoDI 5000.67, *Prevention and Mitigation of Corrosion on Military Equipment*, February 1, 2010
- D, CPO, *Corrosion Prevention and Control Planning Guidebook*, Spiral 3, December 2011
- USD(AT&L) Memorandum, *CPC Direction*, November 12, 2003
- DUSD(I&E) memo, *Facilities and Infrastructure Corrosion Direction Criteria documents*, March 10, 2005.

Each military service issues its own CPC-related policies and guidance as well as pertinent financial instructions that delineate how appropriated funds can be spent. The service-level policies tend to describe CPC requirements as a subset of overall actions in the management and operation of military installations.

SERVICE-SPECIFIC INSTALLATION MANAGEMENT POLICIES AND PROCESSES

Department of the Army

ARMY FACILITIES AND INFRASTRUCTURE ORGANIZATIONS

The Assistant Secretary of the Army for Installations, Energy, and Environment (ASA[IE&E]) provides strategic direction for Army installations and facilities in all matters relating to infrastructure, energy, and the environment. The DASA(APL) is

[7] Appendix B provides a complete listing of the primary DoD and service-level CPC policy and guidance.

responsible for the development and oversight of Department of the Army acquisition policies and lifecycle logistics policies and procedures for materiel development and total lifecycle management of weapon and support systems. The only F&I responsibilities of the DASA(APL) are those in his role as CCPE. The CCPE mission is to oversee the department's activities on corrosion control.

The Office of the Assistant Chief of Staff for Installation Management advises the ASA(IE&E) and issues policies. The Installation Management Command (IMCOM) is the primary command responsible for compliance with DoD-approved standards and methods as they apply to Army installations and real property. IMCOM is responsible for implementing Army CPC policy for facilities;[8] however, other commands have facilities and real property, including Army Materiel Command (AMC), Army National Guard (ARNG), U.S. Army Reserve (USAR), and Space and Missile Defense Command (SMDC). For example, SMDC controls the activities on Kwajalein Atoll.

The objectives of the Army's CPC policy are to design, construct, and maintain dependable and long-lasting structures, equipment, plants, and systems; conserve energy and water resources; reduce costs due to corrosion, scale, and microbiological fouling; ensure compliance with Environmental Protection Agency (EPA), Department of Transportation, Occupational Safety and Health Administration (OSHA), and other applicable regulations and guidance. The CPC programs of IMCOM and other commands (e.g., AMC, ARNG, USAR, and SMDC) are incorporated as part of the entire facility lifecycle, including design, construction, and operation. These individual commands report to ACSIM for facilities as well manage their own facilities. Each region and Army garrison is required to have a trained corrosion program manager to address training and certification requirements. The establishment of corrosion prevention advisory teams and contractor corrosion teams, as described in the DoD *Corrosion Prevention and Control Planning Guidebook*, is the responsibility of the design agent and is required for all projects with a programmed amount of $5 million or more; however, CPC measures must be considered for all construction, repair, and maintenance projects, regardless of cost or funding source.

Each command (e.g., AMC, ARNG, USAR, and SMDC) establishes corrosion control programs for the inspection of utility plants, systems, and structures to determine the cause of any failure; use of corrosion-resistant materials in replacement and new installations when it is cost-effective in terms of the lifecycle; and procedures for the proper operation and maintenance of cathodic protection systems.

The Assistant Secretary of the Army for Civil Works (ASA[CW]) heads all activities for civil works. The Chief of Engineers is an element of the Headquarters (HQ) Army Staff. The USACE is a direct reporting unit of the HQ Army and advises the Chief of Civil Engineers and ASA(CW). The USACE provides military and civil works engineering services, with the Chief of Engineers tasked with

[8] Army Regulation (AR) 420-1, *Army Facilities Management*, Rapid Action Revision, August 24, 2012.

maintaining Army corrosion control design guidance and preparation and revising tri-service technical publications concerning corrosion prevention. The USACE is actively involved in the ESEP[9] Coordinating Panel and WBDG decisions and upgrades.

The Engineer Research and Development Center, Construction Engineering Research Laboratory, (ERDC-CERL) is part of the U.S. Army Engineer Research and Development Center, which is the integrated USACE's research and development organization. ERDC-CERL conducts infrastructure and environmental sustainment R&D. The CERL supports ERDC's research and development mission, work that includes RDT&E and other investigations into CPC-related requirements, including projects funded by the D, CPO. ERDC is a subordinate organization of the USACE, while CERL is a subordinate laboratory to ERDC.

ARMY POLICY AND GUIDANCE

The following policies have been issued by the Department of the Army for facilities:

- The principle F&I corrosion guidance is set out in AR 420-1, which directs the Chief of Engineers to maintain tri-service-related corrosion technical publications and clearly delineates roles and responsibilities of the Army organization as it relates to F&I-related CPC.
- Technical manuals, engineering technical bulletins, public works technical bulletins, and the WBDG criteria (which the Chief of Engineers actively supports) provide to the field more specific Army CPC information and guidance.

Department of the Navy

NAVY FACILITIES AND INFRASTRUCTURE ORGANIZATIONS

The Office of the Chief of Naval Operations (OPNAV) N4 (Deputy Chief of Naval Operations for Fleet Readiness and Logistics) serves as the resource sponsor for Navy installations and provides policy and direction on matters of programming and budget preparation. OPNAV N4 also provides vision and goals for Navy infrastructure.[10]

The Commander, Navy Installations Command (CNIC), the Echelon II command under the Chief of Naval Operations, is responsible for Navy-wide shore installation management. The CNIC is responsible for programming, prioritizing, and budgeting for Navy MILCON programs, special projects, demolition, and other shore investments.

[9] The ESEP comprises senior engineers from OSD and each of the military services.
[10] OPNAV Instruction (OPNAVINST) 11010.20H (Draft), *Facilities Project Instruction*, p. 2.

Naval Facilities[11] Engineering Command (NAVFACENGCOM) is the shore facilities systems command with Navy acquisition executive and head of contracting agency authority for facility planning, design, construction, services, utilities, facilities maintenance (public works), environmental, and real estate. NAVFACENGCOM manages the DON shore facilities lifecycle. The Command acquires and manages capabilities for the Navy's expeditionary combat forces, provides contingency engineering response, and enables DON energy security and environmental stewardship. NAVFACENGCOM provides specialized inspections of airfield pavements, corrosion and cathodic protection, water tanks, bridges, paints and coatings, and thermal plants. NAVFACENGCOM also provides specialized engineering for pier and wharf condition assessments, marine and offshore structures, shore-based diving systems, fleet moorings, underwater construction, magnetic silencing facilities, and underwater cable facilities.

Three NAVFAC specialty centers also engage in corrosion prevention and control:

- The Engineering and Expeditionary Warfare Center (EXWC) provides specialized facilities engineering, technology solutions, and life-cycle management of expeditionary equipment to the Navy, Marine Corps, federal agencies, and other DoD clients. NAVFAC's Warfare Center represents the consolidation of the NAVFAC Engineering Service Center, the NAVFAC Expeditionary Logistics Center, the Specialty Center Acquisitions NAVFAC, and the NAVFAC Information Technology Center. The Navy Crane Center leads the Navy's shore-based Weight Handling Program,[12] establishes policy, and provides engineering, acquisition, technical support, training, and evaluation services to all Navy shore activities. Corrosion-related deficiencies are addressed during the Crane Center's inspections.
- The Engineering Innovation and Criteria Office manages the DoD Criteria Program through the ESEP. The Criteria Office ensures the latest proven technologies are incorporated into criteria as a result of the ESEP and ESEP Coordinating Panel discussions and approvals.

Department of Navy Policy and Guidance

The following are among the corrosion-related policies issued by the Department of the Navy:

- Navy CPC guidance includes F&I work input and control procedures, specific processes within the NAVFAC Business Management System, engineer construction bulletins, and more than 28 maintenance and operations

[11] NAVFAC delivers facilities engineering and acquisition services for the Navy and Marine Corps as well as unified commanders and DoD agencies. NAVFAC work is planned and executed through its component commands. (Source: OPNAVINST 5450.348)

[12] The Navy's Weight Handling Program covers items such as shore-based cranes, derricks, and related special-purpose services equipment.

manuals and publications. The Navy also follows WBDG-hosted criteria and related information.

- Secretary of the Navy Instruction (SECNAVINST) 5000.2e identifies the roles and responsibilities of NAVFAC, including systems engineering and integrated logistics support (ILS) actions for acquisition programs. SECNAVINST 5000.2e also identifies operations and maintenance (O&M) and sustainment actions related to facilities and infrastructure.

- OPNAVINST 5430.348 discusses NAVFAC's roles and responsibilities in support of the Navy and delineates F&I corrosion, cathodic protection, and access to SMEs. OPNAVINST 11010.20G focuses on project development and funding rules and limitations and addresses cathodic protection requirements.

- NAVFAC, *Guide for Architect Engineer Firms Performing Services for the Marine Corps Air Station, Cherry Point, North Carolina*, Revision 5, September 2003, calls for corrosion protective coatings and cathodic protection on Marine Corps facilities.

- Naval Facilities and Installations (NAVFACINST) 7040.5G delineates NAVFAC products and services available to the NAVFAC customer base, including corrosion-related support.

- NAVFAC has an internal business management process that ensures consistent and appropriate processes are conducted across the enterprise. One document of note is the *Marianas Navy and Marine Corps Design and Construction Standards* (September 2011).[13] This guide very clearly delineates CPC risks and actions required to mitigate corrosion in the high-risk area in Guam.

- NAVFAC architects and engineers use the WBDG-hosted criteria. The documents listed above are representative of guidance provided to the field.

- Numerous other documents guide CPC actions in the field. For example, *Cherry Point A-E Guide* calls for corrosion protective coatings and cathodic protection on Marine Corps facilities. Although the form NAVMC 2688 prescribes SRM best practices, it does not call out CPC specifically.

[13] The Marine Corps follows NAVFAC SRM and construction guidance, and Marine Corps F&I staffs interact heavily with NAVFAC (Marine Corps construction support is provided by NAVFAC). As a consequence, the Navy's policies and guidance are relevant to Marine Corps, as well.

Marine Corps Facilities Management Organization

In 2011, the Commandant of the Marine Corps (CMC) directed a reorganization of the Installations and Logistics Department, Headquarters Marine Corps (HQMC), which included the creation of MCICOM as subordinate to the Deputy Commandant for Installation and Logistics (DC I&L).

DC I&L serves as the resource sponsor for Marine Corps installations and provides policy and direction on matters of programming and budget preparation. Within DC I&L the Assistant Deputy Commandant for Facilities (ADC[LF]) provides vision and goals for all Marine Corps infrastructure, including 24 active component installations and the Marine Forces Reserve infrastructure.

The Commander, Marine Corps Installations Command (COM MCICOM), is the Echelon II command responsible for worldwide installation management. As the single authority for all Marine Corps installations matters, MCICOM exercises command and control of regional installation commands, establishes policy, exercises oversight, and prioritizes resources to optimize installation support to the operating forces, tenant commands, Marines, and family members. COM MCICOM is responsible for programming, prioritizing, and budgeting for MILCON programs, facilities SRM projects, demolition, and other facility investments. One Marine Corps general officer serves as both COM MCICOM and ADC(LF).

Similar to the Commander, Navy Installations Command, the Marine Corps relies on NAVFAC as its primary design, construction, and facilities support contract execution agent. In some areas, such as Japan, the Marine Corps also relies on the USACE to fill this role. MCICOM sets priorities, defines requirements, and obtains funding. NAVFAC is a key partner in delivering and maintaining sustainable facilities and infrastructure, which enables energy security and environmental stewardship.

MCICOM consists of a headquarters located in Washington, DC, and four subordinate regional commands:

- Marine Corps Installations East (MCIEAST)
- Marine Corps Installations West (MCIWEST)
- Marine Corps Installations Pacific (MCIPAC)
- Marine Corps Installations National Capital Region (MCINCR).

This unified command system increases the management and operations of the installations with a clarification of authority and responsibility.

MCICOM standardizes all installation functions as far as possible across the Marine Corps, with hopes of better supporting the warfighting mission.

In addition to the Secretary of the Navy (SECNAV) and NAVFACENGCOM guidance, Headquarters Marine Corps[14] and field organizations have issued the following corrosion-related guidance:[15]

- Marine Corps Order (MCO) P5090.2A, *Environmental Compliance and Protection Manual*, provides Marine Corps policies and responsibilities for compliance with environmental statutes and regulations as well as the management of Marine Corps environmental programs, including guidance with regard to corrosion control and prevention on certain real property assets.
- MCO P11000.12C, *Real Property Facilities Manual*, Volume II, "Facilities Planning and Programming," provides procedures to plan and program facilities requirements for Marine Corps installations.
- MCO P11000.7C, *Real Property Facilities Manual*, Volume III, "Facilities Maintenance Management," provides guidance and instructions concerning real property facilities maintenance management, including controlled inspection programs.
- MCO P11000.5G, *Real Property Facilities Manual*, Volume IV, "Facilities Projects Manual," provides policy and guidance for the preparation, submission, review, approval, and reporting of facilities projects at Marine Corps installations.
- Marine Corps installation planning and design teams use the unified facility criteria (UFCs) and *Whole Building Design Guide* criteria for in-house design efforts.

Department of the Air Force

Air Force Facilities and Infrastructure Organizations

The Secretary of the Air Force for Installations Environment and Logistics provides guidance, direction, and oversight for all matters related to plans, policies, programs, and budgets relative to installations and the environment. The Deputy Assistant Secretary of the Air Force (Installations) provides guidance, direction, and oversight of matters pertaining to the shaping and strengthening of Air Force installations in support of personnel and logistical combat capability.

The Air Force Civil Engineer (HQ USAF/A7C) operates, maintains, and protects the sustainability of Air Force installations through engineering and emergency response services. The A7C also provides policy, funding, direction, and oversight

[14] There is heavy interaction between Marine Corps Facilities Management staffs and NAVFAC. The NAVFAC guidance on procedures for executing NAVFAC support missions is also applicable to Marine Corps work performed by NAVFAC.

[15] These documents are representative of guidance provided to the field.

to major commands and bases for facilities and infrastructure. The A7C also leads DoD in developing efficient and sustainable installations through the use of innovative enabling technologies and installation asset management process transformation. The A7C divisions include asset management and operations, planning, programs, resources and readiness, and emergency management.[16] The AFCEC provides installation engineering services at more than 75 locations worldwide. AFCEC missions include facility investment planning, design and construction, operations support, real property management, readiness, energy support, environmental compliance and restoration, and audit assertions, acquisition and program management. AFCEC participates in the ESEP and the associated coordinating panel to ensure relevant CPC guidance is available and accessible to the Air Force.

The Air Force Research Laboratory (AFRL) is dedicated to the discovery, development, and integration of war fighting technologies for air, space and cyberspace forces. Of the three AFRL branches—Materials Integrity Branch (AFRL/RXSA), Acquisition System Support Branch (AFRL/RXSC), and Logistics Systems Support Branch (AFRL/RXSS)—only AFRL/RXSA and RXSS are involved with corrosion prevention and control technology development.

- AFRL/RXSA provides materials/processing consultation services and specialized technical consultation in the application of a variety of materials and processes, including structural and electronic materials, organic matrix composites, adhesives, bonded repair, seals, sealants, elastomers, coatings, corrosion, welding, non-destructive inspection, electrical grounding, and aging issues related to wiring/electrical components.
- AFRL/RXSS helps identify supportability issues that may lead to high maintenance costs, low systems readiness levels, or flight safety problems and works to resolve issues through the application of best practices or the use of advanced technology. AFRL/RXSS arranges for demonstrations of new materials and process technology, fosters technology insertion demonstration projects, and conducts programs to solve problems related to the detection, control, and prevention of corrosion or chemical deterioration.

Air Force Policy and Guidance

Air Force policy and guidance includes a number of documents that link F&I CPC performance to mission support. The following have specific CPC references:

- Air Force Policy Directive (AFPD) 32-10 requires investment-level determinations and assessments should be made relative to mission support. Although not specifically stated, such actions would require CPC consideration.

[16] Air Force Civil Engineering Support Agency (AFCESA), Air Force Center for Engineering and Environment (AFCEE), and Air Force (AF) Real Property Agency reports to A7C (on October 1, 2012) to be combined into one SUPERFOA.

- Air Force Instruction (AFI) 21-101 requires that facilities function in support of aviation CPC and aircraft and equipment maintenance management missions.
- Air National Guard Instruction (ANGI) 21-105 discusses facilities and corrosion and requires that funding be requested for facilities in support of the corrosion control program.
- AFI 32-1054 delineates responsibilities and general requirements for corrosion control programs at major commands and bases.
- AFI 32-1065 assigns maintenance responsibilities and requirements for electrical grounding systems on Air Force installations. The instruction references multiple times cathodic protection and CPC for pipelines and electrical systems where grounding is required.
- AFI 32-1084 has multiple references to cathodic protection and corrosion. The instruction identifies where corrosion control facilities, such as corrosion control hangars and maintenance facilities, should be planned and programmed.
- AFI 63-101 establishes the Air Force CCPE as the senior CPC enterprise official.
- ETL 01-1 provides a generic design checklist for developing functional, reliable, and maintainable facilities and includes multiple references to corrosion design requirements.
- ETL 96-5 presents reflective coating criteria for hangar concrete floors.
- ETL 03-04 presents alternate fuels E85 and B20.

DoD Acquisition Guidance and CPC-Related Construction Criteria

Effective implementation of good CPC practices and results depends on a successfully executed acquisition process. Overarching guidance is received from the Federal Acquisition Regulation (FAR), the Defense Federal Acquisition Regulation Supplement (DFARS) and the *Defense Acquisition Guide* (DAG). While it was not the intent of the FICE study to provide an exhaustive description or assessment of the acquisition process, a few words are necessary to provide context for the comments received during the study team's interviews and questionnaire evaluations.

The actual procurement process begins with the identification of the requirement and continues to the creation of a statement of work and the associated contract documents and realization of a completed facility contract. The acquisition strategy defines the contract type and delivery methods, such as design-build (DB) or design-bid-build (DBB).

- During a DB acquisition, the request for proposal (RFP) includes a scope of work (project program) and defines the associated performance criteria required to achieve a successful constructed facility. The DB contractor retains the architect-engineer to develop the design documents and subsequently accomplishes the work.

- A DBB contract begins with a fully designed facility provided by either an architect-engineer firm retained by the government or by an in-house government design team. The USACE has several standard designs for facilities. The successful bidder is awarded the contract to construct the facility according to the government-provided design and specifications.

Key to all contracts are the criteria developed and maintained by DoD, the military services, and other government agencies. The use and enforcement of these criteria ensure the government receives sustainable facilities that are built according to industry-accepted standards. The contracting process uses these standards as the basis of the procurement to establish acceptable levels of quality and acceptance.

Criteria and Specifications

The National Institute of Building Sciences is a non-profit, non-governmental organization that brings together representatives from government, the professions, industry, labor, and consumer interests to identify and resolve problems and potential problems that may hamper the safe construction of structures. The institute serves the public interest by supporting advances in building sciences and technologies for the purpose of improving the performance of our nation’s buildings, while reducing waste and conserving energy and resources.

The NIBS hosts the *Whole Building Design Guide*[17] and the NAVFAC *Design-Build Master*, as well as the criteria relevant to the associated missions of its members. DoD funds support NIBS and the criteria effort.

The criteria listed in the WBDG is based on industry standards that are usually written and maintained by a standards organization, such as the American National Standards Institute (ANSI), ASTM International, the Institute of Electrical and Electronic Engineers (IEEE), National Association of Architectural Metal Manufacturers, and many others. The use of such industry standards ensures uniformity and consistency and cuts down on the cost and time it takes to create new criteria.

[17] Although the WBDG is managed by NIBS, overall development is guided by a board of directors and advisory committee, which consists mostly of the federal agencies involved in facility design and construction. The development of WBDG content is a collaborative effort among federal agencies, private sector companies, nonprofit organizations, and educational institutions.

Also, maintaining uniformity allows for interoperability between the governmental and non-governmental organizations working together.

SRM and military construction projects use industry-accepted construction and sustainment practices, materials, and equipment for both acquisition documentation and to guide work performed in house by government employees. This can only be accomplished through the use of well-documented and easily accessible criteria.

Three major criteria categories apply to facilities and corrosion control and prevention: UFCs, unified facilities guide specifications (UFGSs), and performance technical sections:

- *Unified facilities criteria*. UFCs provide planning, design, construction, sustainment, restoration, and modernization criteria and apply to the military departments, the defense agencies, and the DoD field activities. UFCs are distributed electronically and are effective upon issuance. See Appendix C for a list of key UFCs applicable to CPC.

- *Unified facilities guide specifications*. The UFGSs are a joint effort of the U.S. Army Corps of Engineers, NAVFAC, the Air Force Civil Engineer Center, and the National Aeronautics and Space Administration (NASA). UFGS specify construction for the military services. See Appendix C for a list of key UFGSs applicable to CPC.

- *Performance technical specification* (PTS). A PTS provides generalized technical requirements that apply to multiple facility types. PTSs add clarification to the fundamental requirements section of an RFP and are applicable to more than one project.

Although unified across the military services, not all criteria are applicable to all DoD components or participating organizations. UFCs and UFGSs that only apply to a certain organization are denoted by the document number. Also, one of the service branches, known as the preparing activity, is the custodian of each UFC/UFGS and manages the update and currency of the document in consultation with other service subject matter experts (SMEs).

Military Construction Requirements

MILCON projects are projects that exceed allowable thresholds of military service and locally funded SRM projects. Military construction includes "any construction, development, conversion, or extension of any kind carried out with respect to a military installation, whether to satisfy temporary or permanent requirements, or any acquisition of land or construction of a defense access road (as discussed in section 201 of title 23 of the USC)."[18] A military construction project includes all construction work necessary to produce a complete and usable

[18] Military construction includes conversions, alterations, additions, expansions, extensions, and complete replacements, as defined by 10 USC Chapter 169, Section 2801.

facility or a complete and usable improvement to an existing facility. Military construction is defined by 10 USC 2801 and addresses several project types of varying size and urgency. According to DoDD 4270.5, *Military Construction*, which provides guidance on MILCON program management, UFCs and UFGSs must be used to the greatest extent possible for planning, design, and construction (restoration or modernization) of facilities, regardless of funding source.

Appendix B lists the larger body of policies, guidance, and criteria that should be used in the design and construction of a MILCON project.

Sustainment, Restoration, and Modernization Program

Facility sustainment is defined by DoD Financial Management Regulation, Volume 2B, Chapter 8. Sustainment includes regularly scheduled maintenance as well as cyclical repairs or replacement of components over the expected service life of facilities. Because of obsolescence, sustainment alone cannot extend the life of a facility indefinitely, but the lack of full sustainment results in a reduction in service life that is not recoverable in the absence of recapitalization funding. Repair or replacement required earlier than expected because of a lack of sustainment is known as restoration.

Restoration and modernization (RM) involve the renovation or reconstruction activities needed to keep existing facilities modern and relevant in an environment of changing standards and missions. RM extends the service life of facilities, restores lost service life, or updates and alters a facility for adaptive reuse. RM includes restoration, modernization, or replacement of facilities, but not the acquisition of new facilities. RM may also include the demolition of deteriorated facilities if demolition is part of the renovation process. Repair of facilities is defined in 10 USC 2811, as "a project to restore a real property facility, system, or component to such a condition that it may effectively be used for its designated functional purpose." The section provides language on prohibitions related to new construction additions and delineates congressional notification requirements.

Successful execution of SRM programs by the military services is essential to ensure facilities continue to meet mission requirements. Corrosion prevention and control represent a very large area of SRM focus. Identifying CPC deficiencies, then determining how and when to resolve those deficiencies, is a major challenge for the F&I community. Consequently, CPC management is an essential part of the ongoing initiative to sustain DoD's facilities and installations.

Chapter 3
Key Drivers of Corrosion-Related Costs

DoD's total annual corrosion-related cost for facilities and infrastructure is $1.904 billion.[1] By focusing on maintenance costs other than family housing, the FICE study team narrowed the corrosion-related facility maintenance costs total to $1.549 billion.

The team then assessed the relationship between the cost drivers[2] identified by representatives from the 30 installations that received a questionnaire and the cost drivers identified in the most recent F&I cost-of-corrosion study, which was completed using FY2008 data.

IDENTIFYING POSSIBLE COST DRIVERS

The questionnaires sent in advance of the study team's visit or teleconference included questions that were intended to isolate, from an installation's perspective, the root causes of corrosion spending:

Thirty-four organizations (from the 30 sites surveyed) provided cost driver information. The team had access to sufficient data to conduct a cost analysis for 31 of the 34 organizations. The team used the information from these responses as the basis of cost data comparison.

The questionnaire responses identified 36 unique maintenance objects as top cost drivers for corrosion. Many of the responses were too broad to isolate the costs to an individual item or end-item. In many cases it was necessary to compile the costs for the subparts that relate to the maintenance object identified by the installations. For example, the database of available FY2008 maintenance data does not identify the costs for the end item "boiler, heat exchange." It was, therefore, necessary to consolidate the costs for the various parts to identify the maintenance and corrosion costs for boilers.

Several installations identified facility age as a top cost driver. Although age has an obvious effect on SRM costs for facilities and installations, it is not possible to isolate the costs associated with age from the other objects. Therefore, facility age

[1] These costs are based on FY2008 data from an LMI 2010 facilities and infrastructure cost-of-corrosion assessment (*The Annual Cost of Corrosion for the Department of Defense Facilities and Infrastructure: 2007–2008 Update*, LMI Report DL907T2, Eric F. Herzberg, Amelia Kelly, Norman T. O'Meara, July 2010). LMI estimated the cost of corrosion for DoD facilities and infrastructure in FY2008 was approximately $1.904 billion.

[2] Cost drivers are identified as expended corrosion-related maintenance costs inclusive of labor, material, and preventive and corrective actions.

was not considered in the cost evaluation. Table 3-1 lists the 36 unique maintenance objects identified by the facilities organizations.

Table 3-1. Cost Drivers That Relate to Unique Maintenance Objects

Survey-identified maintenance objects		
◆ Boiler, heat exchange	◆ Fuel distribution	◆ Plumbing
◆ Bridge	◆ Fuel storage	◆ Roof
◆ Building exterior–paint	◆ Generator	◆ Signage
◆ Compressor	◆ Hot water tank	◆ Spillway
◆ Cooling, chiller	◆ HVAC	◆ Staircase
◆ Culvert, ditch	◆ Hydrant	◆ Steam and distribution
◆ Electrical enclosure	◆ Insulation	◆ Swimming pool buildings
◆ Exterior electric	◆ Ladder	◆ Tank, tower
◆ External facilities, structure	◆ Lighting, etc.	◆ Valve
◆ Facility age[a]	◆ Mold	◆ Wash rack
◆ Fence	◆ Non-potable water storage and distribution	◆ Water pipe
◆ Fire Suppression	◆ Pavement, concrete	◆ Waterfront[b]

Note: HVAC = heating, ventilation, and air conditioning.

[a] Because age is not an object that can be maintained, age-related costs cannot be isolated from the other 35 objects.

[b] Waterfront includes dry docks, piers, and wharfs.

DoD Backlog or Deferred Work

Deferred maintenance projects—issues that remain unresolved because of a lack of funding, scheduling conflicts, or operational requirements—are a cost consideration when prioritizing limited SRM budgets; however, installations currently do not record essential and deferred maintenance. With no accurate record of the extent of the SRM backlog, corrosion-related deficiencies for that backlog are also unknown.

Although reporting of deferred F&I maintenance is not a requirement, it may include potential future DoD facility-related corrosion costs. At this time, the periodic cost-of-corrosion studies account only for expended costs (funded costs), even though the DoD installations' perspective of cost includes backlog (unfunded costs). Because of this difference in how work is represented, the full F&I costs related to corrosion may be considerably higher.

The study team noted potential future work pitfalls as backlog work continues to increase in today's funding environment. These pitfalls may include an escalating amount of work not being performed because of budgetary restrictions, an increasing cost of repair because of deferred maintenance, and the need to replace or recapitalize deferred items that require corrosion work at a much higher cost (versus being repaired or maintained). The deferred F&I maintenance also has a direct impact on overall DoD readiness, as capabilities of weapon systems are closely tied to F&I.

PRIVATIZATION

The FICE study did not include the related corrosion costs of privatized facilities and infrastructure, such as leased space and buildings (housing) and privatized utilities. These assets are fully maintained and managed by private firms.

VALIDATING COST DRIVERS

The next step was to identify the corrosion and maintenance costs for the 35 remaining objects and isolate the costs for the surveyed installations from all other installations. The team searched the FY2008 military services' maintenance data to find the corrosion and maintenance costs associated with each object. These are presented in Table 3-2.

Table 3-2. Corrosion and Maintenance Costs Comparison

	Surveyed installations		All other installations	
Maintenance object	Corrosion cost	Maintenance cost	Corrosion cost	Maintenance cost
Boiler, heat exchange	$3,793,815	$19,045,108	$6,662,698	$49,922,418
Bridge	$15,411	$334,137	$145,268	$1,895,313
Building exterior–paint	$39,424,013	$41,715,790	$83,163,728	$92,356,062
Compressor	$2,509,073	$26,207,423	$7,598,440	$63,376,746
Cooling, chiller	$4,268,433	$31,994,522	$14,161,676	$88,609,960
Culvert, ditch	$1,160,720	$19,345,654	$6,039,973	$62,098,768
Electrical enclosure	$1,471,411	$14,537,162	$3,513,144	$42,030,721
Exterior electric	$16,464,653	$132,855,433	$44,010,536	$418,399,498
Facilities, structure	$94,173,358	$618,349,700	$293,435,608	$2,200,156,560
Fence	$960,519	$12,080,373	$3,357,928	$53,748,561
Fire suppression	$2,351,517	$13,794,098	$6,327,199	$45,706,347
Fuel distribution	$280,063	$14,797,135	$1,000,595	$38,802,522
Fuel storage	$68,664	$2,350,607	$2,437,207	$35,388,562
High voltage	$16,815	$2,731,261	$1,202,974	$7,074,380
Hot water tank	$1,586,900	$4,915,860	$3,378,057	$21,956,472
HVAC	$70,350,288	$470,177,404	$171,173,873	$1,560,443,605
Hydrant	$694,367	$5,324,470	$1,488,676	$20,430,018
Insulation	$355,627	$2,101,134	$608,075	$3,484,065
Ladder	$454,691	$1,361,238	$527,178	$4,221,367
Lighting, etc.	$1,033,320	$61,225,831	$4,546,730	$175,476,753
Mold	$4,871,701	$5,185,476	$13,801,832	$14,254,287
Non-potable water distribution	$3,202,836	$24,700,293	$14,365,391	$90,879,873
Pavement, concrete	$9,296,994	$62,421,976	$12,623,976	$218,910,688
Plumbing	$45,841,002	$301,412,349	$105,075,739	$836,528,947
Roof	$7,096,216	$24,871,148	$20,470,491	$73,011,168
Sign	$1,147,880	$21,645,861	$5,672,882	$90,494,466
Spillway	$51,784	$692,477	$16,881	$1,020,818
Staircase	$2,771,194	$6,863,718	$3,189,544	$15,005,667
Steam and distribution	$1,048,841	$11,377,117	$2,734,525	$21,078,578

Table 3-2. Corrosion and Maintenance Costs Comparison

Maintenance object	Surveyed installations		All other installations	
	Corrosion cost	Maintenance cost	Corrosion cost	Maintenance cost
Swimming pool buildings	$2,955	$139,871	—	—
Tank, tower	$948,108	$4,468,358	$1,050,744	$15,950,305
Valve	$2,941,008	$13,076,031	$6,546,524	$29,400,896
Wash rack	$305,003	$1,508,985	$889,345	$3,138,913
Water pipe	$2,489,641	$26,798,932	$6,166,511	$68,954,383
Waterfront	$7,406,229	$30,745,719	$4,742,124	$23,568,552
All other cost drivers	$92,523,612	$965,536,745	$273,586,405	$2,740,534,365
Totals	$423,378,662	$2,996,689,396	$1,125,712,476	$9,228,310,604

The 35 objects identified by the surveyed installations account for more than 75 percent of corrosion-related costs (see Table 3-3). The catchall for “all other cost drivers” actually equates to roughly 400 database entries. It is reasonable to assume the objects identified by the installations are key corrosion-related cost drivers because the 35 objects identified in the survey account for 75 percent of the total costs and the remaining 400 objects account for only 25 percent of the costs. It is, therefore, safe to conclude the 35 objects identified are primary cost drivers.

Table 3-3. Relationship of Survey-Identified Cost Drivers to Total Costs

	Surveyed installations		Non-surveyed installation	
	Corrosion cost	Maintenance cost	Corrosion cost	Maintenance cost
Total cost for 35 objects	$330,855,050	$2,031,152,651	$852,126,071	$6,487,776,240
All other cost drivers	$92,523,612	$965,536,745	$273,586,405	$2,740,534,365
Total	$423,378,662	$2,996,689,396	$1,125,712,476	$9,228,310,604
35 objects as a % of total	78.1%	67.8%	75.7%	70.3%

To assess how well the 35 unique maintenance objects relate between the two populations of installations (surveyed and non-surveyed installations) and whether perception relates to the broader reality—the team ranked the objects by corrosion cost. Ranking by corrosion cost identifies possible cost mitigation opportunities. Table 3-4 shows the comparison of the corrosion cost–based rankings for the surveyed installations and all other installations for which the team had data.

Table 3-4. Comparison of Corrosion Cost–Based Rankings

Maintenance object	Surveyed installations		All other installations	
	Corrosion cost	Ranking	Corrosion cost	Ranking
Facilities, structure	$94,173,358	1	$293,435,608	1
HVAC	$70,350,288	2	$171,173,873	2
Plumbing	$45,841,002	3	$105,075,739	3
Building exterior–paint	$39,424,013	4	$83,163,728	4
Exterior electric	$16,464,653	5	$44,010,536	5
Pavement, concrete	$9,296,994	6	$12,623,976	10
Waterfront	$7,406,229	7	$4,742,124	18
Roof	$7,096,216	8	$20,470,491	6
Mold	$4,871,701	9	$13,801,832	9
Cooling, chiller	$4,268,433	10	$14,161,676	8
Boiler	$3,793,815	11	$6,662,698	12
Non-potable water storage and distribution	$3,202,836	12	$14,365,391	7
Valve	$2,941,008	13	$6,546,524	13
Staircase	$2,771,194	14	$3,189,544	23
Compressor	$2,509,073	15	$7,598,440	11
Water pipe	$2,489,641	16	$6,166,511	15
Fire suppression	$2,351,517	17	$6,327,199	14
Hot water tank	$1,586,900	18	$3,378,057	21
Electrical enclosure	$1,471,411	19	$3,513,144	20
Culvert, ditch	$1,160,720	20	$6,039,973	16
Sign	$1,147,880	21	$5,672,882	17
Steam and distribution	$1,048,841	22	$2,734,525	24
Lighting, etc.	$1,033,320	23	$4,546,730	19
Fence	$960,519	24	$3,357,928	22
Tank, tower	$948,108	25	$1,050,744	28
Hydrant	$694,367	26	$1,488,676	26
Ladder	$454,691	27	$527,178	32
Insulation	$355,627	28	$608,075	31
Wash rack	$305,003	29	$889,345	30
Distribution	$280,063	30	$1,000,595	29
Storage	$68,664	31	$2,437,207	25
Spillway	$51,784	32	$16,881	34
High voltage	$16,815	33	$1,202,974	27
Bridge	$15,411	34	$145,268	33
Swimming pool buildings	$2,955	35	—	—

With the exception of waterfront and non-potable water storage and distribution, the top 10 rankings of the two populations are fairly similar. (The disparity in rankings for waterfront may be an artifact of the composition of the sample.)

Using regression analysis to compare the cost amounts for the maintenance of selected objects between surveyed and all other installations, the regression analysis produces an estimate of the degree of correlation between the two data sets. Table 3-5 shows a very high R-squared value of 0.972459246. This supports our contention that the corrosion cost driver surveyed installations are representative of the general population of installations.

Table 3-5. Corrosion Cost Regression Statistics

Multiple R	0.986133483
R-square	0.972459246
Adjusted R-square	0.971598597
Standard error	3572586.344
Observations	34

Note: R-squared, the coefficient of determination (or R^2), is used to predict future outcomes on the basis of related information. R^2 values are between 0 and 1.0, with 1.0 having perfect correlation and 0 having no correlation. Values greater than 0.5 indicate strong correlation.

The team also ranked the 35 unique maintenance objects by corrosion cost as a percentage of total maintenance cost. This highlighted any objects that are cost drivers because of generally high maintenance cost as well as objects for which costs are mostly related to corrosion.

Table 3-6 shows the comparison of the corrosion percentage–based rankings for the surveyed installations and all other installations for which the team had data. The rows highlighted in yellow are the objects ranked as top 10 cost drivers (from Table 3-4) based on corrosion percentage. Paint and mold are, by far, the greatest cost drivers in terms of corrosion cost as a percentage of maintenance. Aside from exterior electric,[3] all top 10 cost drivers in terms of corrosion cost fall within the top 20 cost drivers in terms of corrosion cost as a percentage of maintenance. Table 3-4 in the previous section uses aggregated corrosion costs by maintenance object as a percentage of the maintenance cost for that specific type of object. This percentage (or ratio) is just another way of ranking items. Since different parameters are used to portray different data, the rankings in Table 3-4 and Table 3-6 are not going to be identical. Each has unique dollar-amount denominators, which means the transformation from dollar amounts to percentages is not a "uniform dollar transformation" across all objects.

[3] Exterior electric is ranked 21st (for both surveyed and all other installations) based on corrosion as a percentage of maintenance; it is ranked as 5th based on corrosion cost.

Table 3-6. Comparison of Corrosion Percentage–Based Rankings

Maintenance object	Surveyed installations		All other installations	
	Corrosion percentage	Ranking	Corrosion cost	% of maintenance
Building exterior–paint*	94.5%	1	90.0%	2
Mold*	93.9%	2	96.8%	1
Staircase	40.4%	3	21.3%	6
Ladder	33.4%	4	12.5%	18
Hot water tank	32.3%	5	15.4%	12
Roof*	28.5%	6	28.0%	4
Waterfront*	24.1%	7	20.1%	7
Valve	22.5%	8	22.3%	5
Tank, tower	21.2%	9	6.6%	28
Wash rack	20.2%	10	28.3%	3
Boiler	19.9%	11	13.3%	14
Fire suppression	17.0%	12	13.8%	13
Insulation	16.9%	13	17.5%	8
Facilities, structure*	15.2%	14	13.3%	15
Plumbing*	15.2%	15	12.6%	17
HVAC*	15.0%	16	11.0%	20
Pavement, concrete*	14.9%	17	5.8%	31
Cooling, chiller*	13.3%	18	16.0%	10
Hydrant	13.0%	19	7.3%	26
Conveyance line, etc.	13.0%	20	15.8%	11
Exterior electric*	12.4%	21	10.5%	21
Electrical enclosure	10.1%	22	8.4%	24
Compressor	9.6%	23	12.0%	19
Water pipe	9.3%	24	8.9%	23
Steam and distribution	9.2%	25	13.0%	16
Fence	8.0%	26	6.2%	30
Spillway	7.5%	27	1.7%	34
Culvert, ditch	6.0%	28	9.7%	22
Sign	5.3%	29	6.3%	29
Bridge	4.6%	30	7.7%	25
Storage	2.9%	31	6.9%	27
Swimming pool buildings	2.1%	32	—	—
Distribution	1.9%	33	2.6%	33
Lighting, etc.	1.7%	34	2.6%	32
High voltage	0.6%	35	17.0%	9

Note: Maintenance objects with an asterisk (*) are listed as top 10 cost drivers based on corrosion cost.

COST DRIVER SUMMARY

The 35 drivers of corrosion-related cost identified in responses to our survey represented more than 75 percent of the overall estimate of corrosion-related costs. The sample of installations surveyed was intended to serve as good representatives of all of DoD; the sample appeared to do this well, at a minimum, for the top cost drivers.

Chapter 4
Military Construction Corrosion Assessment: Guam Replacement Hospital

The FICE study team reviewed corrosion mitigating technology and corrosion prevention industry standards and materials for both new and existing facilities and evaluated a planned MILCON project to identify whether these standards had been included in the planning and execution of the project.

The D, CPO selected P-65271 Hospital Replacement, Naval Hospital Guam (see Figure 4-1), to provide a perspective on an extreme exposure zone and the extent of CPC-related considerations that were documented in the facility's planning, authorization, design, and construction.

Figure 4-1. P-65271 Hospital Replacement, Naval Hospital Guam

BACKGROUND

Naval Hospital Guam was originally constructed in 1954 as a 330-bed facility. It is centrally located on the island of Guam with Naval Station Guam to the south and Andersen Air Force Base to the north. The ESI for Guam is 19 of 20 (20 being most corrosive environment).

Guam has one of the harshest environments in terms of corrosion. Relative humidity is continually higher than 72 percent.[1] Because Guam is a small island,

[1] http://ns.gov.gu/climate.html.

facilities on the island are exposed to constant ocean spray, torrential rains, and typhoons, all of which contribute to the high ESI rating. In addition, the island's soil is characteristically coral based, sandy, and corrosive in nature.

The existing hospital layout impedes the efficient flow of health care work. The distance between key work units is lengthy, and inpatient care functions are dispersed throughout the building spaces. Aside from the inefficient and unwieldy building layout, the condition of building systems (electrical, HVAC, lighting, etc.) and overall structure have deterior-ated after 60 years of exposure to tropical conditions. The facility also does not comply with current seismic and life safety codes, and it exhibits multiple deficiencies related to water seepage. In many parts of the building, the roof is failing.

The tropical environment of Guam contributes to the high costs of hospital operations and continual repair. Structural design elements of the existing facility are not amenable to renovation, and the hospital, as it is currently configured, cannot be renovated economically when compared to the cost of new construction. Therefore, the decision was made to recapitalize the facility by constructing a new hospital and demolishing the existing structure.

The P-65271 Guam Replacement Hospital is a $446,450,000 multistory replacement hospital[2] that will provide inpatient medical, surgical, obstetrical, and intensive care units, as well as outpatient primary and specialty care clinics, emergency medicine, medical logistics, and support functions. Supporting facilities include all site work, utilities, and parking. The hospital replacement was designed in accordance with criteria prescribed in DoD UFC 4-510-01,[3] UFC 4-010-01,[4] Americans with Disabilities Act and Architectural Barriers Act (ADA/ABA), Americans with Disabilities Act Accessibility Guidelines (ADA/ABAAG), and applicable energy conservation policy. Operations and maintenance manuals, comprehensive interior design, and commissioning will be provided.

THE MILITARY CONSTRUCTION PROCESS

Planning and Programming

Planning and programming of MILCON projects generally follows standard military service or DoD submission and approval processes. The installation or service agency, in this case the OSD Tricare Management Activity (TMA), determines the requirements during the planning stage and prepares a DD Form 1391 project documentation for review and prioritization by the chain of command, with the eventual submission for OSD, service, and ultimately congressional approval.

[2] Demolition of the existing hospital will occur in a future project.

[3] DoD, UFC 4-510-01, *Design: Medical Military Facilities*, February 8, 2009 (updated November 2012).

[4] DoD UFC 4-010-01, *Minimum Antiterrorism Standards for Buildings*, October 8, 2003 (updated February 9, 2012).

Planners and programmers follow service-specific processes for determining the need and scope of MILCON projects based on mission requirements. This includes determining mostly functional and other planning requirements or limitations, such as siting, safety clearance, environmental impact, and other infrastructure support (e.g., utilities).

The DD Form 1391 is the principal project justification document to express the user's facility-related needs, request authorization through the service's chain of command, and apply for authorization and funding from Congress. A DD Form 1391 must include detailed, informative statements as to why the project is needed. It must also identify every primary and supporting facility required to complete the construction, as well as the unit of measure, unit quantity, and unit cost for each facility. For projects that require congressional authorization, 10 USC 2853, establishes legal requirements for staying within the project scope of work identified by a DD Form 1391.

The DD Form 1391 includes only minimal technical details. This restriction extends to information related to corrosion, unless the project consists of facilities inherently more vulnerable to the effects of corrosion. For example, a steel water storage tank construction project may call out protective coating and cathodic protection requirements. The focus of the DD Form 1391 is on functional requirements and may include only a brief description of CPC requirements. The CPC costs are included as part of the overall engineering discipline costs (electrical, structural, etc.), except when specialized CPC work is required and the project document includes separate line items for CPC costs.

Acquisition Strategy

If approved by the OSD or the service's chain of command, the project is included in the OSD or service's input into the President's budget for service and congressional approval. Upon approval and authorization, the service will authorize and transfer funding to an execution agent to proceed with the design and construction of the MILCON project. For the most part, the two primary DoD execution agents, NAVFAC and the U.S. Army Corps of Engineers, execute MILCON projects following either the design-build or design-bid-build delivery processes.

The execution agent will schedule design charettes with TMA and service and user representatives to review and establish the design goals of the MILCON project. During the initial design charette, the service or execution agent will validate the general requirements of the DD Form 1391 document, determine the functional requirements in greater detail, and discuss some of the special technical requirements (including CPC) that may significantly affect the overall cost estimate. The service or execution agent will generally determine the appropriate design and construction process based on technical difficulty or any specialized nature of the project requirements, execution time requirements and limitations, desired flexibility in utilizing more innovative (and perhaps more corrosion-resistant products), and the desired amount of government control over the final product.

Design and Construction

Most technical requirements, including CPC requirements, are determined and specified during the design stage. The design process includes several stages during which government engineers and installation representatives have an opportunity to review and comment on the design documents (drawings, construction specifications, design analysis, and cost estimates). The best time to discuss technical requirements (including CPC), application of new technology, and cost issues is during the initial design charettes or functional analysis concept development (FACD) meetings, which occur early in the design processes.

Specific technical details and technology are identified during the design process, but only after analyzing the project requirements and cost limitations. Tradeoff decisions (typically, first cost vs. long-term benefit) also may be made throughout the design process after communication with installation personnel. Designers will, on occasion, consult with service subject matter experts for advice and provide design documents for review and comment.

In addition to overarching service policies and guidance, planners and engineers refer to UFCs to determine requirements, more so during the design process than the planning and programming process. Designers may also research technical bulletins, such as engineering and construction bulletins (ECBs), as well as industry codes or standards for the latest guidelines. Some of these may state specific CPC requirements, while others may only imply CPC requirements.

The USACE, NAVFAC, and the military installations may develop local guidelines above and beyond UFCs to properly address site-specific requirements when extreme environments or other unique local issues exist. For example, NAVFAC has instituted the *Marianas Design and Construction Standards* (MDACS) document for projects in Guam. The MDACS is a compilation of years of experience about the performance of different materials in Guam. Some MDACS standards are related to corrosion prevention and mitigation and are referenced by P-65271.

CPC Assessment of MILCON Project P-65271

DD Form 1391

The DD Form 1391 for the Naval Hospital Guam contains the information typically found in a DD Form 1391 document: statements of need and justification and general square footage requirements of the main and supporting facilities.

The following wording from the project's DD Form 1391 requires the use of CPC-specific design criteria and describes the level of deterioration:

> 10. *Description of Proposed Construction*: The hospital replacement will be designed in accordance with criteria prescribed in DoD UFC 4-510-01, Evidence Based Design principles… O&M Manuals, comprehensive Interior Design and commissioning will be provided.
>
> 11. *Current Situation*: Besides the inefficient and unwieldy building layout, the condition of building systems and overall structure have deteriorated on account of the lengthy exposure to tropical conditions on Guam for sixty years. The facility does not comply with current seismic and Life Safety Codes and exhibits multiple deficiencies related to water seepage through the walls. In many parts of the building, the roof is failing. The tropical environment of Guam contributes to the high costs of hospital operations and continual repair. Structural design elements of the existing facility are not amenable to renovation and the hospital as configured cannot be economically renovated in comparison to new construction.
>
> …Impact if not provided: Life cycle operating costs for the obsolescent and antiquated infrastructure and building systems are expected to continue to significantly increase in response to the facility exceeding it's useful economic life which prevents an effective economy of operation for both the facility as well as healthcare operations.

Note that UFC 4-510-01 contains several references to the requirement of corrosion design features. Referencing O&M manuals and commissioning services increases the likelihood that lifecycle management of the facility will be positively affected.

Pre-Design Actions

The Navy is designated as the using service of the new hospital, and the Navy assigned NAVFAC Pacific as the project execution agent. Because of the complexity and specialized requirements (facility and equipment) for the hospital construction, NAVFAC Pacific, after consultation with NAVFAC HQ, determined that design-bid-build was the best acquisition strategy for this project.

DBB contracts provide a facility that is fully designed by a government-retained architect or engineering firm. The facility is built according to the government's design and specifications after the fully designed facility is awarded to a construction contractor.

NAVFAC Pacific held an initial design charette, or a functional assessment and conceptual design meeting, with various medical and user representatives. The major focus of the FACD was as follows:

1. Validate the DD Form 1391 document requirements.

2. Review the program for the design document provided by the Bureau of Medicine and Surgery representatives. Discuss and determine any adjustments needed and agree to the scope of work for the project design.

3. Discuss and agree to a path forward regarding issues or requirements that could significantly affect the overall cost.

As a result of the FACD and several other design charettes, the design architect-engineering firm and the government agreed on a basis of design (BOD) to proceed to design completion. Work included civil, landscape architecture, structural, architectural, plumbing, mechanical, electrical, and communications design; removal of hazardous materials from the existing structures to be demolished; and demolition of existing structures and site improvements.

The BOD focused on the functional requirements, but acknowledged the adverse environment of Guam and the need to provide a low maintenance exterior design. The BOD also identified numerous criteria that would be followed by the different architectural and engineering disciplines during the development of the design, many of which included CPC requirements.

The following were among the many criteria documents identified in the BOD:

1. UFC 4-510-01, *Design: Medical Military Facilities*. This manual provides new and existing facility mandatory policies and procedures for programming, planning, design, construction, and commissioning of safe, sustainable, functional, and durable facilities that shall have reasonable and appropriate construction, sustainment, maintenance, and operations costs throughout their expected service life. The document focuses primarily on facility design and construction requirements, and it addresses O&M upgrade projects where feasible and cost effective. The document includes design and construction requirements by specific architectural and engineering discipline, including sections or paragraphs on site-specific environmental conditions, corrosion control, infection prevention and protection, and industry standard best practices for the protection of facilities' infrastructure.

2. UFC 3-440-05N, *Tropical Engineering* (January 16, 2004). Contains numerous CPC requirements based on many years of collective lessons learned by NAVFAC engineers.

3. *Marianas Region Architectural and Construction Standards* (MRACS). Contains many architectural and engineering requirements to respond to the harsh Guam environment. It incorporates the collective knowledge of

the architect/engineering community in Guam and at NAVFAC Pacific, and CPC subject matter experts. The MRACS has been updated and is now the MDACS.

4. COMNAVMARIANAS, *Installation Appearance Plan* (September 2007) includes architectural requirements aid in corrosion prevention.

5. UFC 3-600-01, *Fire Protection Engineering for Facilities* (April 17, 2003) includes material selection and corrosion control requirements for fire sprinkler piping.

6. 2006 *International Building Code*[5] includes chapters on building occupancy classifications; interior finishes; foundation, wall, and roof construction; fire protection systems (sprinkler system requirements and design); and materials used in construction.

7. National Fire Protection Association (NFPA)-70, *National Electrical Code*,[6] includes many material selection requirements for corrosion resistance.

In addition to accommodating the criteria above, design engineers and architects often consulted with NAVFAC corrosion prevention and control SMEs regarding appropriate materials selection, protective coatings, and other corrosion prevention alternatives.

Design Actions

The major proposed exterior closure includes cast-in-place concrete walls with a synthetic finish system, metal windows and window-walls with high performance safety glazing, fluid applied membrane roofing for low-pitched areas, and metal roofing tiles over fluid applied membrane roofing for steeply pitched roof areas. Exterior materials were designed in accordance with the MDACS.

Numerous CPC-related requirements were identified and specified as part of the design. The following are examples of CPC requirements specified throughout the design:

- Higher quality concrete (impervious to water/chloride intrusion), which helps mitigate corrosion of the reinforcing steel and concrete
  - Concrete with silica fume, fly ash
  - A low water-to-cement ratio

[5] International Code Council, *2006 International Building Code.*

[6] National Fire Protection Association, NFPA-70, *National Electrical Code*.

- Use of aggregates that inhibit the alkali-silica reaction, which can result in the premature degradation of the concrete
- Use of galvanized steel, stainless steel, and non-metallic components and appurtenances for better corrosion resistance than carbon steel.

- Protective coatings on exterior metals. Wherever it is not feasible to use galvanized or stainless steel materials, protective coatings are applied to the material to provide a barrier against the harsh environment and help mitigate corrosion. For example, the metal roof tiles have a factory-applied protective coating.

- Aluminum or stainless steel doors and windows in lieu of coated carbon steel for better corrosion resistance. Galvanized steel, stainless steel, and aluminum hardware were also used in lieu of carbon steel. Isolation of dissimilar metals using dielectric inserts or protective coatings after proper surface preparation will help prevent galvanic corrosion.

- Coated copper core and copper cooling fins for air conditioning units in lieu of typical uncoated copper cores with aluminum fins. The all-copper materials will avoid dissimilar metal issues experienced with the copper core–aluminum fin equipment. The protective coatings will give the equipment additional protection from the harsh tropical environment.

- Protective coatings or a double wall underground fuel storage tank (in accordance with environmental laws). The protective coatings or outer wall provide corrosion protection to the inner steel tank.

- Double-wall fuel pipe with a composite outer pipe for corrosion protection of the inner steel pipe.

- Cathodic protection (CP) if the pipe will be buried steel. Protective coatings protect against corrosion on aboveground storage tanks and aboveground piping.

- Heating and hot water systems.
  - Water treatment to control corrosion and scale.
  - O&M manuals and operator training that ensure proper operation and to avoid premature breakdown or failure, including corrosion-caused failures, because of improper operation.
  - Coatings and CP on buried heat distribution system for corrosion protection.
  - Coated aboveground piping and equipment for corrosion protection.

- Options for polyvinyl chloride (PVC) or ductile iron underground pipe (either is acceptable) for long-term performance in the soil environment at the hospital site.
- Quality control requirements (testing/verification) for specialized systems to ensure proper construction as specified.

These requirements were identified based on requirements in UFCs, the documented experience of a design community familiar with the tropical environment of Guam, and after consultation with CPC subject matter experts. Many of the requirements are beyond those specified at installations in less aggressive environments, but are adequate from a life-cycle cost perspective.

Construction

The DoD FICE study team conducted a site visit to the hospital construction site (see Figure 4-2) and discussed the project with both the Navy construction management staff and the contractor representatives. Both parties indicated the hospital is being constructed as designed. During the site visit, the contractor pointed out several CPC features, such as galvanized steel structural framing and nonmetallic storm water drainage pipe, which are called out in the specifications.

While there have been change requests, some are beneficial. For example, one approved change was to glue (instead of fasten) the coated metal roof tiles to the concrete roof deck. This would preclude penetrations into the concrete roof deck and may prevent water/chloride intrusion into the concrete, which could result in accelerated corrosion of the reinforcing steel. Another change request added a new water treatment system after the source of water supply was changed.

Figure 4-2. New Guam Hospital under Construction

MILCON SUMMARY

The FICE study team evaluated and assessed the project identified as P-65271 Hospital Replacement, Naval Hospital Guam, to provide a perspective on an extreme exposure zone and the extent of CPC-related considerations that were documented in the facility's planning, design, and construction.

Project planning documents acknowledged the effects of the harsh tropical environment, and pre-design charettes resulted in a basis of design that noted numerous design criteria documents that contain references to corrosion prevention and control. Specific CPC requirements were identified during the design phase.

Project design documents also specify numerous CPC material and installation requirements based on criteria documents, the experiences of the design community, and after consultation with CPC subject matter experts.

By including CPC requirements from the beginning of the planning and documentation phases, the appropriate decisions have been made to address lifecycle requirements with improved performance over time. The manner in which CPC has been addressed in P-65271 is a model for other MILCON projects, regardless of corrosion risk.

Table 4-1 summarizes the team's assessment of the project's different phases described previously.

Table 4-1. Summary of Project Phases

MILCON phases	Documents	Relevant CPC content	Assessment
Planning	UFC 4-510-01 DD Form 1391 (generate) Program for design document	General	Primarily functional requirements. Acknowledges the effects of the harsh tropical environment on Guam and identifies certain criteria to be used.
Pre-design actions	DD Form 1391 (validate) UFC 4-510-01 Basis of design	Significant	BOD identifies numerous criteria with CPC requirements.
Design actions	Drawings and specifications (based on UFGS and various criteria documents)	See paragraph, "Design Actions"	Numerous CPC requirements included. CPC requirements are adequate. See paragraph, "Design Actions."
Construction	Drawings and specifications (site visit and discussions with contractor and Navy construction management officials)	See paragraph, "Construction"	Generally being constructed as designed. Additional water treatment system added due to change in water supply. See paragraph, "Construction."

Chapter 5
Corrosion Prevention and Control Technologies

Technology development, transition, and application play an important role in corrosion prevention and control for DoD facilities and infrastructure. The inclusion of new technologies at critical stages of the F&I lifecycle can extend a facility's life, reduce SRM costs, and minimize total lifecycle costs.

New CPC technologies are often the result of collaborations across industry, academia, and DoD to explore innovative or non-standard technical processes and products that represent progressive developments within the field of corrosion prevention. Such technology includes the practical application of products, processes, and procedures, (zinc coatings, cathodic protection, oil-less chillers, replacement of metal conduit with plastic, more durable electrical connectors, better management systems, etc.).

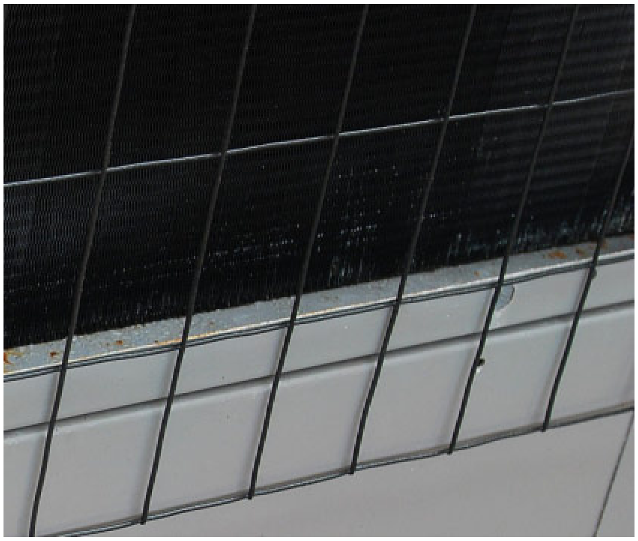
CHALLENGES OF INTRODUCING AND MAINSTREAMING NEW TECHNOLOGIES

While new technologies may be promising, there are challenges associated with introducing and accepting such technologies in the culture of facility engineers and maintainers. These challenges can include the higher initial costs, unique maintenance and training requirements, and aversion by the procurement community to conduct sole-source procurements. Other challenges include overcoming the unfamiliarity of new technology by facility engineers and the associated risks with unknown reliability levels.

Any new technology or material must be carefully researched and its use coordinated before it can be included in a criteria document or procurement. DoD depends on industry to validate these new technologies and ensure materials, processes and equipment will endure and be cost effective for the full life of a facility. If DoD determines there is a specific need for a technology not covered by any criterion, process, or equipment, only then may RDT&E funds be used for technology development.

The D, CPO funds and shares with the military services the costs of an active research and demonstration program for CPC-focused materials, equipment, and processes associated with F&I. ERDC-CERL, NAVFAC Engineering and Expeditionary Warfare Center, and Air Force Civil Engineer Center work to validate these technologies.

Appendix D describes the CPC technology RDT&E program within DoD.



Coated HVAC fins have been proven to extend the life of a system.

The projects presented in this chapter are examples of technologies that could be applied to DoD's facilities and infrastructure. Other examples are listed in Appendix D. New technology aids in the efficient and effective operation of F&I. To achieve these goals, the technology must be mature, and implementation should be guided by a business case analysis.

Technology Development Funding

For the D, CPO technology demonstration program, subject matter experts analyze existing technologies, and determine if gaps exist between the available technology and the requirements of the department and the military services. If gaps do exist, DoD may identify funds to investigate technologies to address them.

RDT&E appropriations fund the development of DoD equipment, material, or computer application software. This includes services, equipment, components, materials, end items, and weapons. Corrosion-related RDT&E projects occur at the military service level. In some cases, D, CPO technology funding may be used to demonstrate or expand the awareness of these military service RDT&E projects among the F&I community.

Turbocor pumps provide an oil-less solution in mitigating corrosion (Navy Hospital Guam).

Examples of Corrosion Technology Projects

The CPC technology development efforts of DoD, other government agencies, and industry have resulted in solutions and strategies that can extend the life of facilities and infrastructure. The continued transfer of successful CPC-related RDT&E technologies into facility criteria will ensure CPC is integrated into the design, construction, and sustainment of future facilities and infrastructure.

DoD Projects

The D, CPO project program often interacts with other DoD programs to ensure the best possible CPC-related decision can be made throughout the facility and infrastructure lifecycle. The three projects highlighted below changed the criteria hosted on the WBDG and improved the processes F&I lifecycle management. The first project is a D, CPO–funded demonstration project for a specific coating system. The second is a demonstration of the LifeJacket® technology, which is used to repair failed construction in a highly corrosive environment. The third project is an Office of Naval Research (ONR)/NAVFAC RDT&E project that demonstrated and assessed several CPC-related aspects of the floating double-deck pier (FDDP).

D, CPO Project FAR-13: Coating System for Corrosion Prevention and Fire Resistance for Metal Structures (2006)

The objective of this 2006 D, CPO–funded project was to apply a coating system to metal structures to prevent corrosion and provide fire resistance. The performance of the coating system was monitored over 1 year to demonstrate the technology for use across DoD.

The technology involves the use of innovative epoxy intumescent coatings that contain nano-corrosion inhibitors and can insulate the steel to delay it from weakening when exposed to high temperatures. These coatings require virtually no maintenance and can withstand extreme environmental conditions. The coating system was applied to one hangar and one additional structure at the Rock Island Arsenal, Illinois.

Changes to UFGS 07 81 00, *Spray-Applied Fireproofing*, were published in February 2011 as a result of this research.

D, CPO Project N-F-229: Integrated Concrete Pier Piling Repair and Corrosion Protection System

Reinforced concrete pilings at Ford Island on Pearl Harbor, Hawaii, suffered from significant corrosion of the steel rebar, which resulted in the spalling of the concrete and loss of load-handling capacity. The technology used consisted of a commercially available integrated concrete repair and cathodic protection prefabricated in a fiberglass jacket, referred to as LifeJacket. The LifeJacket technology restores load-handling capacity of structures, minimizes the opportunity of a recurrence of corrosion on the reinforcing steel, resulting in a reduction in maintenance and lifecycle costs and increases service life. The repair project served as test program for the LifeJacket technology.

This integrated pile repair corrosion protection system involved a high-purity expanded zinc-mesh cathodic protection anode that was mounted to a durable, stay-in-place fiberglass form. This positioned the anode material the appropriate distance relative to the steel rebar in the piling. The form creates an essential annular space for filling with concrete material to complete or improve the structural repairs to the piling. A supplemental bulk anode was added to protect the submerged portion of the pile and minimize current demand on the lower portion of the anode mesh. The system comes ready to install, with all components pre-positioned and fixed in place. The external jacket material is a durable fiberglass shell, equipped with a unique interlocking seam for easy installation by contractors.

The system provides a viable repair alternative to reinforced concrete piles that have been contaminated with chlorides and require significant crack and spall repairs. It is also a possible alternative when full pile replacement is not economically feasible. Based on the test results to date, the LifeJacket technology functions as advertised. The pile-reinforcing steel is adequately protected from corrosion, and no further corrosion-caused spalling or delaminations are anticipated for at least 20 years in the portions of piles with LifeJackets.

From August 2007 through August 2010, NAVFAC EXWC conducted a series of tests after system commissioning to determine the operating status and effectiveness of the LifeJacket galvanic protection technology. These tests and the analysis were funded by D, CPO Project N-F-229; results from the project have been included in a pending draft rewrite of UFC 3-570-02 *Cathodic Protection Design*.

ONR/NAVFAC RDT&E Project Floating Double-Deck Pier (Formerly Called the Modular Hybrid Pier)

The FDDP project developed a pier design that could be built off site, deployed and assembled on site, disassembled, and redeployed. As the project progressed, the goal was to develop a floating double-deck pier that is modular and reconfigurable and minimizes piling by more than 60 percent, reduces seafloor footprint by more than 50 percent, and provides a 100-year service life for waterfront concrete structures to reduce maintenance, construction, and demolition costs.

Achieving a 100-year service life is a function of quality aggregate, mixture design, and concrete cover. The FDDP resulted in several valuable corrosion prevention lessons. For example, the founding shaft, which replaces piles for structural stability, was dipped in a passivated bath and cathodic protection was used to protect the submerged surfaces of the shaft, regardless of the material. The secondary shaft steel pipe pile that was driven into the seafloor pipe pile was coated with a corrosion-preventing glass flake epoxy (developed by

NAVFAC EXWC) and passively cathodically protected by two 93-pound aluminum anodes. The test bed was also outfitted with current flux and voltage potential sensors that can monitor corrosion behavior and protection of electrically isolated post-tensioning hardware, other concrete reinforcement, and the founding shafts. The electrical resistivity of well-cured, high-volume fly ash concrete is considerably less than what is required to prevent corrosion of the reinforcing steel.

The following technologies were transitioned as a result of the FDDP project:

- *High-strength, light-weight concrete*. The concrete mixture used 33 percent Class F fly ash as a partial replacement for Portland cement. Pre- and post-stressed reinforcement in two directions ensured crack closure. Changes in UFGS 03 31 29 now allow use of slag and fly ash at 50 percent replacement for Portland cement.
- *Service-life modeling*. NAVFAC EXWC developed a novel method for predicting the long-term service life of marine concrete using STADIUM®, a state-of-the-art multimechanistic, finite element software.[1] Other projects have benefited from the STADIUM method, including the Navy's FDDP, piers, dry docks, and wharves; the third lock of the Panama Canal; U.S. Department of State facilities; and various public works and commercial projects.

Major changes to UFGS 03 31 29, *Marine Concrete*, now allow users to specify performance of the structures in terms of service life and the tools provided to verify performance during construction. Designing structures using the guidelines provided in UFGS 03 31 29 will result in greater readiness and more sustainable development, as corrosion of steel is the primary cause of premature failure of reinforced concrete in marine environments.

The FDDP project was supplemented with D, CPO funds for corrosion monitoring in FY2006 (Project FNV04, *Modeling of Advanced Waterfront Materials*) and for the use of high-volume fly ash in concrete in FY2009 (Project F09NV07, *High Volume Fly Ash Concrete*). See Appendix D for more detail on these projects.

Other Government and Industry Technology Improvements

CPC technology developments include non-defense government agency, private sector, and other non-governmental corrosion-related technology projects and improvements. The following examples include two projects that, although partially funded by a government agency, were carried out by non-governmental organizations.

The two projects reflect technology research and development that may ultimately result in changes to industry standards (such as ANSI, American Iron and Steel Institute [AISI], or the American Concrete Pipe Institute). DoD benefits from this

[1] D, CPO Project F10NV10 demonstrated this technology. See Appendix D for more detail.

kind of research and the resulting demonstration work because it uses industry reference standards that directly affect DoD construction and SRM projects.

Rock Bolts and Steel Sets for Sub-Surface Reinforcement of the Yucca Mountain Repository

The purpose of this study was to understand the environmental effects (such as corrosion and oxidation) on the support structure of the proposed underground Yucca Mountain repository. The research was conducted by the University of Nevada, Reno, for the U.S. Department of Energy and the University Community College System of Nevada. Funding for the project was provided by the U.S. Department of Energy, Office of Civilian Radioactive Waste Management.

Two classes of material were assessed:

- Rock bolts (split set friction type rock stabilizers [SS 46], Swellex Mn-24 and AISI 4340 steel) that are used to reinforce the tunnel
- Super alloys (such as Alloy 22 [UNS N06022], Alloy 282, and Alloy 263) that are used for containers and other components for the underground repository.

Electrochemical and conventional corrosion tests were run on rock bolts obtained from industry and on other steels with desirable properties for rock bolts. Corrosion tests were performed using the electrolyte water chemistry furnished by the Yucca Mountain site; in certain cases, the test results were compared with other electrolytes with impurities. Concentrations of 1×, 10×, and 100× of YM electrolyte, from room temperature to approximately 95°C were used. The tests were performed under nitrogenated and oxygenated conditions to obtain a range of corrosion rates for the materials. Oxidation kinetic studies were performed using thermo-gravimetric measurements on rock bolt steels and super alloys at elevated temperatures to identify the oxidation mechanisms. Both isothermal and continuous heating measurements were made to obtain the data between 600°C and 1,100°C in pure oxygen atmosphere for predetermined periods of exposures (48 hours for the super alloys and 100 hours for the high-strength, low alloy [HSLA] steels).

The Yucca Mountain project identified the corrosion behavior of Alloy 22, HSLA steels, AISI-SAE 4340 steel, and high-temperature oxidation kinetics.[2]

Acceptance Criteria for Reinforced Concrete Pipes

Reinforced concrete pipe is widely used by the Florida Department of Transportation (FDOT) in installations that must remain in service over many decades; only extremely slow deterioration rates are accepted. Concrete cracks often happen shortly after placement, so the FDOT must decide early in the pipe's lifespan

[2] http://hrc.nevada.edu/data/unqualified/ORD-FY04-019/ORD-FY04-019_final_report.pdf.

whether the cracks are of little consequence to future performance and accept the pipe, or if repair or replacement is needed.

Funded by FDOT, the University of South Florida (USF), Department of Civil and Environmental Engineering, set out to

- determine the influential parameters responsible for crack healing in in-place reinforced concrete pipes,
- determine what may constitute a maximum crack with amendable autogenous healing and sufficient cover to mitigate reinforcement corrosion, and
- formulate guiding models detailing pipe crack acceptance criteria during construction.

The USF investigation included a literature review, a review of past FDOT experience, laboratory experiments, and an evaluation of experiment results to formulate a model guideline.

Corrosion tests showed that significant reinforcement wire corrosion could take place in a short time in reinforced concrete pipe with 0.100-inch cracks, and that corrosion damage was considerably slower when the cracks were 0.020 inches wide. Corrosion was aggravated by the presence of moderate chloride ion contamination (500 parts per million, or ppm), but active steel corrosion occurred even without such contamination.

The reinforced concrete pipe project resulted in two key benefits:

- USF developed a predictive model for corrosion development in cracked reinforced concrete pipe.
- Crack width acceptance guideline models proposed for discussion included a restrictive alternative.
  - A 0.020-inch crack is allowable only when environmental chloride is no greater than 500 ppm.
  - A less restrictive alternative allows 0.020-inch cracks with environmental chloride up to 2,000 ppm.
  - A sliding option allows environmental chloride up to 2,000 ppm when pipe service life is progressively derated to zero for cracks widths between 0.020 inch and 0.100 inch.

In all models the acceptable width defaulted to 0.010 inches if the other conditions were not met.

ROI CONSIDERATIONS FOR D, CPO PROJECTS

The D, CPO follows the guidance contained in Office of Management and Budget Circular A-94, *Guidelines and Discount Rates for Benefit-Cost Analysis of Federal Programs*, when evaluating potential technology projects. Return on investment (ROI) is the ratio of projected cost avoidance to the initial required investment. ROI evaluations apply a widely used engineering economic technique to assess where capital funding should be applied to a specific investment opportunity.

ROI is computed and applied to corrosion technology development projects for three reasons:

- To help evaluate corrosion R&D projects submitted for funding and implementation to determine the economic effect of the projected results.
- To identify technologies that show promise for wider application within DoD and elsewhere.
- To assess the projected overall benefit of successful projects in reducing the incidence and effects of corrosion.

ROI is reassessed 2 years after a project demonstration is completed. The objective is to assess the worthiness of required implementation documentation and overall project impact. This objective applies to all five areas of evaluation: the project's documentation, assumptions, responsiveness to mission needs, ROI, and performance to expectation. The actual ROI is not recomputed because data is insufficient after only 2 years to perform this computation.

The 2-year ROI assessment is not meant to be used as an accurate figure to adjust original individual project ROI projects or recompute composite average ROI projections. The ROI assessment is used to facilitate management decisions regarding the following:

- Application of additional resources to ensure completion of an important project
- Application of additional resources to further develop or expand the technology
- Transfer of the technology to other applications
- New applications of the technology
- Development of new derivative technologies to respond to added CPC requirements.

TECHNOLOGY READINESS LEVELS

The *Department of Defense Corrosion Prevention and Mitigation Strategic Plan* identifies actions to select and fund corrosion research projects and integrated product team activities to enhance and improve corrosion prevention and mitigation throughout DoD. This includes the coordination of corrosion prevention and mitigation R&D programs on new and existing systems and the transition of new technologies to operational systems.

An important metric of transition planning is the use of technology readiness levels (TRLs). NASA developed a tool that grades technology from TRL 1 (basic principles observed and reported) to TRL 9 (actual system; "flight proven" through successful mission operations). The TRL evaluation tool is among the metrics used by D, CPO for understanding where the technology maturity is at the outset for a particular project and how it advanced during the project.

CPC TECHNOLOGY SUMMARY

The successful development, transition, and application of new CPC technologies reduce the lifecycle cost of facilities and infrastructure by reducing material degradation. Key to mainstreaming new technologies is the transition into construction criteria (e.g., UFCs and UFGSs), improving awareness, and mitigating concerns that the technology might not be as reliable as more mature technologies. Instituting initial costs into total lifecycle costs as compared to other CPC choices is another concern that must be addressed. While new technologies may have higher initial costs than existing technologies, implementation of new technologies may result in significant lifecycle cost avoidance. Demonstration projects establish the reliability and feasibility of technology success in the fight against corrosion and premature failure of facilities and infrastructure.

Chapter 6
Corrosion from the Field-Level Perspective

The FICE study team surveyed 30 installations by questionnaire and site visit or teleconference to identify how installations implement corrosion prevention, control, and mitigation strategies in their facilities and infrastructure. During site visits, the team also viewed an example of corrosion-related deterioration and field-level efforts to combat the associated corrosion.

The survey of installations considered two major groupings: new military construction and existing facilities and infrastructure. For military construction, the objective is prevention: How do you reduce corrosion deterioration throughout the facility's lifecycle by including non-corroding or corrosion resistant materials, correctly applying protective coatings, and using corrosion control technologies as part of the design effort.

Corrosion prevention and control presents a more challenging problem for existing facilities. With limited budgets, sustainment, restoration, and modernization actions address the most urgent deficiencies while maintaining material condition consistent with the operational readiness requirements of the installation. SRM processes may require planning, programming, design, engineering, and acquisitions, each of which has corrosion-related decision events that affect both service life and lifecycle costs.

Planning and Programming

Planning and programming is the essential first step to effectively managing and executing CPC workload. This formal process engages facilities professionals with experience in the infrastructure lifecycle.

Whether a project is simple (such as the application of a coating to mitigate the deterioration of a surface) or complex (such as the justification for a MILCON project), the basic tenets of planning and programming apply.

The FICE study team asked F&I representatives several planning and programming questions:

- Do installations include CPC provisions in their policies and instructions for SRM and MILCON?
- Which corrosion-related criteria are considered in the development of project planning and programming processes and documentation?

- How adequate or effective are corrosion-related criteria in the development of project planning and programming processes and documentation?
- What are the top corrosion-related challenges?
- How are deficiencies identified, prioritized, and addressed?
- How does ESI affect deficiencies?
- Is corrosion-related workload combined with other SRM work to achieve a timely resolution?

General Planning and Programming Concerns or Trends

The study team learned from installation representatives that installation and facility design agents use all available sources of information (such as the WBDG, codes, and other sources of corrosion-specific guidance) to support their planning and programming initiatives. The chief concerns of most installation representatives are the shortage of resources and dearth of trained and qualified personnel. The primary challenge is the cost to maintain an aging infrastructure within an available budget.

Specific Planning and Programming Feedback

The following are among the corrosion prevention and control provisions in planning and programming policy or instructions for SRM and MILCON:

- Most installations rely on NAVFAC or USACE for their design requirements. Additional guidance includes the International Building Code, National Fire Protection Association, UFCs, UFGSs, WBDG, and ECBs.
- The Air Force also uses AFIs (e.g., AFI 32-1054) in conjunction with UFCs, UFGSs, and the WBDG.
- The Marine Corps uses base exterior architecture plans (BEAPs), which call for the use of low-maintenance materials.
- Some installations report that a search of the WBDG brings up too many guidelines, and it is confusing or difficult to narrow down search results to their local requirements. However, specific criteria related to their environment are searched and used out of necessity.
- UFCs are considered for most projects, but the installations rely on the design agents to ensure the criteria are incorporated into the design.
- Based on their experience and knowledge of the unique environmental demands, some F&I personnel look for more corrosion-resistant material than is required by the UFCs (e.g., stainless steel base for transformers).

Uncoated fins on this HVAC system are less than 2 years old.

- The government program management office developed a “common components” document to help with material selection and planning. The use of tropical guidelines is a must because UFC guidelines may not adequately address local environmental needs.
- Some of the best construction practices are in UFCs; however, they may not be a best practice for installations in unique environments (desert, arctic, high ESI zone, etc.). Several installation representatives indicated that geotechnical and utility UFCs are not as useful as they could be.
- Facilities in very high ESI zones or in an area with a high water table require a greater degree of CPC planning for SRM and MILCON because of accelerated corrosion rates.
- Sites in low ESI zones also have their own environmental effects that must factor into corrosion planning, such as earthquakes, high soil alkalinity, high water alkalinity, volcanic ash, wild fires, and others risks that may not be obvious to outside entities.
- Realignment (i.e., base realignment and closure) resulted in additional large tenants for installations. In some cases, host installations were not provided additional manpower and funding resources to support the increased infrastructure management responsibilities. This further limited SRM actions to only critical issues and negatively affected CPC corrective actions.
- Most personnel are more comfortable with familiar construction trade technology than trying something new; however, many are receptive to implementing new technologies if recommended or directed to by a higher HQ.

The following are the top corrosion-related planning and programming challenges cited by the installation representatives surveyed:

- Lack of proper corrosion training.
- Funding shortfalls.
- Facility and infrastructure age.

- Lack of qualified maintenance personnel.
- Energy reduction and associated documentation requirements, environmental regulations, and anti-terrorism force protection (ATFP) requirements are competing for resources and take precedence over CPC needs.
- Facilities that are or may be eligible for consideration for the National Register of Historic Places require significant amount of resources to maintain. Consultation with the applicable state historic preservation office (SHPO) or the federal Advisory Council on Historic Preservation (ACHP) is complex and resource intensive.
- The correction of corrosion-related degradation is viewed as a fact-of-life repair that is necessary over the life of a facility, especially when it negatively affects mission effectiveness.
- Many installations combine CPC requirements with energy and environment projects as a legitimate means of justifying and executing the work.

Wharf deterioration (non-mission-essential) is allowed to continue because of a lack of funds.

Project Acquisition

Acquisition processes heavily influence corrosion prevention and control. The FICE study team asked several acquisition-related questions of both the field and design agents:

- What are the advantages and disadvantages of the various acquisition strategies when addressing corrosion-related deficiencies?
- What contract vehicles types are used in the execution of projects?
- What are the preferred contract vehicles?
- Where do they obtain their information (technical criteria, standards and specifications, etc.) when developing contract vehicles?

- How are corrosion requirements addressed in technical selection factors in the source selection process?
- How effective are quality assurance (QA) and quality control (QC) planning when addressing corrosion-related contract requirements?

General Project Acquisition Concerns or Trends

The team learned from installation representatives that contracting officer support for facility acquisition is essential when obtaining timely resolution of corrosion-related deficiencies. Installations that have in place an array of contract vehicles that are specifically designed to support facilities and infrastructure, especially corrosion prevention and control, are more successful at minimizing the effect of corrosion.

Minimizing delays in the acquisition process will reduce F&I CPC costs. If each phase of the acquisition process is working well, an acceptable level of quality can be achieved.

An example of a corrosion-resistant stainless steel door in a high ESI zone (Guam).

A newly acquired HVAC system with coated fins is placed within protective wall to extend the life of the system (Guam).

Specific Project Acquisition Feedback

CPC is considered in the initial design or planning stages; however, how corrosion-related requirements are addressed depends on the type of contract vehicle used.

- Design-build contracts may include corrosion-related requirements within the RFP. The advantage is the primary contractor has full responsibility for the design and construction of the project or facility, which can expedite project completion. Because the DB contractors tend to maximize profit, essential decisions related to CPC or other important design features are often a secondary consideration.

- Design-bid-build contracts address CPC during the design phase, which is executed by the government contracted architect/engineer (A/E). DBB may have a longer lead time for execution, but this allows the greatest opportunity to address corrosion-related requirements. DBB may use government personnel to perform A/E design functions. This helps in the development and retention of in-house CPC capabilities. Specific technical details and technologies are identified during the design process, and design reviews are conducted frequently; therefore, tradeoffs affecting CPC also occur throughout the design process after communication with installation personnel.

- Indefinite delivery, indefinite quantity (IDIQ) contracts are widely acknowledged as a good mechanism for single discipline project work (such as painting, HVAC, roofing, roads, and electrical). Some installation representatives commented they have IDIQs developed for each major SRM area. IDIQs allow quick delivery order award (within hours, as opposed to months). Many organizations expressed an interest in blanket IDIQ contracts that could be shared by multiple installations or even by multiple services.

- Installation services (sometimes referred to by the sites as base operating support, or base operating support [BOS]—terms are used interchangeably) contracts usually include specific CPC requirements and deliverables, and the contractor must have qualified personnel on staff or must subcontract CPC efforts to qualified personnel. BOS contracts/installation services are widely used across installations because of the need for responsive services.

- Installations prefer a centrally managed multiple-use or multipurpose contracting vehicle for expediency of project execution. Many installation representatives mentioned that contract laws and mandated small business set-aside programs (8[a], HUBZone, SDVOSB, etc.) hinder their ability to procure the best-value solution.

- Quality control is the responsibility of the contractor, and quality assurance is the responsibility of the government. QC plans do not address every element of construction, and some bases are not aware of QA/QC plans that specifically address corrosion requirements.

- Most constructability reviews are conducted by contract managers or public works staff members. The general opinion of installation representatives is that QA and QC is lacking. Specifically, it was noted that contractors do not have the incentive to ensure good QC, and the government does not always have adequately trained personnel to perform effective QA related to CPC.

- DB, DBB, and IDIQ contracts do not include CPC technical selection factors in contract source selection.

- Many installations feel the best value contractor is rarely selected; most contracts are being awarded as "lowest cost, technically acceptable." In addition, not all technical disciplines are represented during technical evaluation boards so some key requirements are missed in the evaluation. Consequently, design solutions may drive higher CPC lifecycle costs.

Better buying power for fences calls for CPC-specific criteria.

- The contracts group must be familiar with facilities acquisition. Supply type functions (purchasing paper, parts, etc.) and the more sophisticated contract actions of DB, DBB, and IDIQ contracting are addressed by separate sections of the FAR; each requires the support of a contracting officer familiar with the specific process. Contract support on some bases was provided by supply contracting offices. Their lack of F&I contracting knowledge impeded SRM progress, drove up costs, and negatively affected mission support.

- Contract requirements of open competition do not allow intelligent buying for purposes of configuration control and standardization (e.g., multiple air conditioning units from different vendors).

The inability to justify sole-source procurements can result in multiple systems that require multiple spare parts and different training for each system.

The brands of air conditioners shown (left to right) are Toshiba, Pioneer, Carrier, and Trane.

CPC Criteria and Technology Assessment

To be successful in conducting SRM and MILCON programs, acquisition documents must include a clear definition of technical standards. This is achieved by utilizing industry construction and sustainment practices, materials, and equipment. The *Whole Building Design Guide* hosts these standards and criteria, which is web accessible. The term "criteria" generally refers to documents that guide all DoD components and participating organizations in terms of facility planning and design, construction, standard operations, and technical and maintenance (e.g., sustainment) requirements. New technology is methodically researched, evaluated, and coordinated before it is included in any WBDG criteria document and subsequent procurements to ensure that it is sustainable throughout the facility's lifecycle.

As part of this study, D, CPO investigated the extent of available criteria and found during a focused keyword[1] search of the WBDG database 427 applicable CPC-related criteria documents, including 71 military specifications and standards, 12 military handbooks, 96 UFCs, 220 UFGSs, and 28 PTSs. These documents contain significant CPC-related content regarding technology standards and best practices for statement of work development for contract RFPs. To see a complete listing of these documents with additional information on criteria and the WBDG, see Appendix C.

Application of criteria into contracts begins with defining the requirement and identifying the type of contract delivery method (DB or DBB) and the contract vehicle (single contract action, delivery order, an IDIQ contract, etc.). The designer of record will take the criteria associated with the scope of work and edit the portions of the UFGS criteria document as well as appropriate contract clauses, tailoring them to the specific requirement. In the case of corrosion, the desired level of detail associated with a building component (window coatings, cathodic protection, etc.) is entered into the relevant criteria documents and attached to the

[1] Corrosion-related keywords are corrosion, cathodic, deterioration, structural deterioration, rust, mold, and mildew.

RFP. The effectiveness or performance of a corrosion-specific edit to the criteria will generally be at the building component level.

CPC General Criteria and Technology Concerns or Trends

The WBDG represents a huge body of work to ensure appropriate technology standards are available when procuring CPC for facilities and infrastructure. The sheer volume of criteria found on the WBDG is not only expansive, it is comprehensive to CPC. The WBDG is the source of information to support the process and put all approved technology in one place so that appropriate standards are applied when procuring CPC technology for F&I. Design agents are very familiar with the WBDG and use it for all levels of MILCON and SRM work. Only a lack of experience or training inhibits the full use of criteria provided within the WBDG.

At the installation level, where engineering and design resources may be limited, there is little time to research available criteria and other design resources. Networking, communities of practice, web research, and other informational forums suffice, but past specifications (with possibly dated criteria) are sometimes used.

The relevance and importance of the WBDG and its hosted criteria must be emphasized to successfully disseminate good engineering practices and solutions. To achieve this objective, field personnel must be trained and fully familiar with the availability and appropriate use of the CPC criteria discussed in Appendix B.

Specific Criteria and Technology Feedback

The FICE study team solicited feedback about criteria use and any associated issues. The team asked questions about information sources (such as criteria, standards, and specifications) used when developing contract vehicles; CPC criteria considered in the development of project planning, programming, and documentation processes; and the use of the WBDG for corrosion-related design decisions. The team also discussed with installation representatives the introduction of new CPC technologies with field and design agents.

The study team was presented with a broad range of perspectives when installation representatives were asked to comment on the adequacy of CPC criteria:

- Although UFCs convey the best universal construction practices, they do not always consider the unique requirements of specific environments (e.g., desert, arctic, high ESI zone).
- At one installation, the UFC identified the use of a certain cable, but that cable failed in only 17 months. Although the installation tried to follow the best practice consistent with the local environment, designers were directed to use the UFC. In another example, a UFC suggested the use of an underground cable that had failed within 13 months.

- Installations prefer to rely on local knowledge and experience when combating corrosion, rather than UFCs and UFGSs, because current UFCs are lacking or do not address corrosion.

- Attempting to change criteria documents is a slow process and is not always responsive to field needs. One installation tried waiver requests, but the fast track process of the MILCON caused the installation to avoid this option because it would take 6 months to get the waiver. One installation developed in-house templates that included corrosion requirements when current UFCs were lacking or did not address corrosion.

- Most installations rely on design agents to use the latest UFCs and UFCSs in their design.

- Some installations specify more corrosion-resistant material than is required by UFCs (for example, use of a stainless steel base for transformers).

- Some installations mentioned that it is very difficult to search UFCs and UFGSs; an easier query method is needed.

The study team also received a broad range of responses when installation representatives were asked about the usefulness and effectiveness of the WBDG for corrosion-related design decisions:

- Installation representatives claimed they use the WBDG
  - *only* if it is part of the initial building plans,
  - for corrosion-related design decisions,
  - as a reference to numerous other criteria,
  - to access the most current design criteria, or
  - for everything.

- Many believe the WBDG has little, if any, relationship to utilities.

- Some were unfamiliar with the WBDG.

- Design requirements in the document are often in conflict.

The FICE study team also asked what information sources, technical criteria, standards, and specifications are used in the development of contract vehicles or the execution of projects (in-house, IDIQ contract, separate contract, etc.).

- Installation representative responses—
  - Most use UFCs, UFGS, and WBDG.
  - Some try to ensure the customer (concept developer) has a voice in the construction and contract administration.
  - For arctic areas, installations use technical criteria, standards, and specifications drawn from their arctic engineering training.
  - Utility design guidelines on the WBDG are used.
  - Some referenced American Society of Mechanical Engineers, National Association of Corrosion Engineers (NACE), applicable building codes, OSHA practices, American Water Works Association, and BEAP.
- Design agent responses—
  - UFCs, UFGSs, and agency-specified guidance or criteria are relied on for working knowledge of CPC systems.
  - Designers write ECBs, engineering technical letters, and design policy letters in the development of contract vehicles and in the execution of projects.
  - Designers may use the Building Information Modeling tool for design.
  - Criteria change requests have been submitted and improvements have been reflected in UFGSs and ECBs.
  - The designer of record is relied upon to provide a sound CPC strategy for the project.

Sustainment, Corrosion Requirements Identification, and Workload Management

The FICE study team asked installation representatives several questions related to sustainment, corrosion requirements identification, and workload management.

- How often are F&I condition assessments conducted? Who conducts F&I condition assessments? What assessment tools were in F&I condition assessments?
- Are corrosion-related deficiencies included as part of the assessments? How?
- What are the qualifications of the assessors?
- Are corrosion-related reporting systems used in planning?
- Are specialized inspections leveraged to ensure corrosion-related deficiencies are addressed?
- What are the cathodic protections, coatings management, and water treatment practices?
- How are failure investigations conducted to determine whether a failure is related to corrosion? To what extent is that information being used?

General Sustainment, Corrosion Requirements Identification, and Workload Management Concerns or Trends

Each military service manages corrosion's effect on sustainment differently. The degree to which assessments are used depends on available resources, trained personnel, and condition assessment tools. As a result, responses to the questions asked were inconsistent.

The expense and ineffectiveness of current condition assessment and maintenance management software inhibit the ability of installations to effectively record and manage corrosion-related deficiencies and needs. Specifically, there were many examples when the work induction process did not allow for tracking of corrosion-related repairs or CPC coding used to identify causes of F&I deterioration. This lack of data on possible corrosion-related failures makes it difficult to paint a true picture of expended costs of corrosion.

The General Fund Enterprise Business System, or GFEBS, is the Army's new web-enabled financial, asset, and accounting management system that standardizes, streamlines, and shares critical data across the active Army, the Army National Guard, and the Army Reserve. This system is being used to enter and track work-orders and replaces the Integrated Facility System (IFS) or MAXIMO. Because of the system's initial financial design intent, the overall system lacks many of the tracking mechanisms that are needed by the department of public works (DPW) to monitor, keep track of, and prioritize day-to-day CPC-related deficiencies for SRM projects. Many sites supplement this system with their own tracking systems because GFEBS does not easily provide the project tracking information the DPW needs to manage projects, and only certain users can access certain sections of GFEBS.

SRM fuels pipeline requires recoating to prevent further corrosion.

Specific Sustainment, Corrosion Requirements Identification, and Workload Management Feedback

It is important to understand the workload requirements of an installation, because those requirements drive resourcing decisions that may prolong the life of the facility. Some installations conduct F&I condition assessments with periodicities that range from 1 year to 5 years; however, some installations have no funding to conduct assessments at all.

The Defense Logistics Agency fuels program has been proactive in conducting regular assessments on fuels facilities (quarterly or annually), which has had a positive effect for all locations.

The FICE study team received the following additional feedback from installations:

- Most installation representatives recommend at least a yearly facilities condition assessment. This helps the installation determine work requirements and mitigate potential corrosion degradation or other deficiencies before having to replace an item entirely.
- For some installations, BOS/installation services contractors conduct and submit facility condition reports annually; however, most assessments, when done by installations, are conducted visually by their building and facility managers.
- Corrosion issues may be noted wherever installations status reporting (ISR) is accomplished.
- Qualifications for inspectors range from on-the-job assessment experience to formal training in the use of Installation Condition Assessment Program (ICAP) tools. Inspections of critical systems, such as in the pavement and hangar areas, tend to require specialized training.

The use of condition assessment tools vary. The following summarize some commonalities:

- Some installations conduct PAVER and ROOFER assessments (the frequency of assessment varies). Many installations do not use PAVER, ROOFER, or BUILDER because of the high personnel cost, training requirements, and cost of licenses for those systems. In addition, these systems require a significant amount of data entry and data upkeep, which is another expense.
- Some installations use MAXIMO, ISRs, or their service-supported work management tools; while some have created their own tool for tracking and entry.
- Although the ICAP tool (which uses BUILDER algorithms) is being used, its use is limited. The tool is too new to evaluate how well it is working.
- For Marine Corps installations, BUILDER evaluations are performed by HQMC-funded consultants.

The FICE study team received the following responses to the question related to including corrosion deficiencies in assessments:

- Some installations indicated that assessments are for “as-is” conditions, based on the item’s functionality (performance) not just corrosion deterioration, and corrosion deficiencies are found when conducting preventive maintenance inspections.
- Most installations use visual inspections and use trends to plan inspections.
- A few installations use UT, Floor scan, x-rays, or cameras.

The study team received the following feedback regarding the condition assessment reporting systems used for corrosion-related planning:

- The condition assessment reporting system is not used specifically to identify corrosion-related deficiencies; rather, it is used to determine the overall condition of facilities and the need to pursue repair actions or projects.
- For some installations, corrosion is part of the checklist and the root-cause of failure is determined. A few installations indicated that corrosion planning is not part of the preventive maintenance program.
- Identifying deficiencies makes future forecasts easier in terms of budgeting funds for supplies, materials, and labor.
- MAXIMO and ICAP have no special “block” to check for corrosion, so corrosion is generally part of the visual assessment.
- If corrosion data is not available in MAXIMO, corrosion-related tasks are difficult to plan or include in planning.

When asked about how they leveraged specialized inspection findings to ensure that corrosion deficiencies are addressed, the installation representatives provided the following responses:

- Some installations validate the contractor reports, then turn them into SRM projects (5-year plan), if necessary.
- Condition assessment scores are used to develop an integrated priority list. If a trend is identified, a request is placed for an engineering analysis. If the shops identify it as a critical problem, then it will be addressed in a repair project. Some installations review the deficiency to determine whether it is an isolated problem or a systemic issue.
- Specialized inspection findings are normally given a high priority. Many times, specialized inspectors note how bad the corrosion is for a given facility or piece of equipment, which then give good justification to fund.

The following are corrosion-related practices and programs of the installations surveyed:

- Cathodic protection is managed and maintained by contractors or in-house personnel, depending on their local processes.
- DLA support of cathodic protection and corrosion control for fuels facilities (storage tanks and pipelines) has been very positive.
- Field checking cathodic protection is programmed into the recurring work program and follows guidelines established by UFC-3-570-06.
- Installations with high soil alkalinity are moving storage tanks and piping systems above ground where possible.
- Aggressive water treatment is conducted on HVAC systems for most locations.
- Some installations pursue component health-monitoring technologies for critical systems, such as boilers or water treatment systems, which carry high labor costs for maintenance and for which the consequences of failure are unacceptable.
- Painting and protective coatings are managed through the BOS/installation services and job order contracts. Most installations maintain an IDIQ paint contract that is able to address interior and exterior painting requirements. Because of a lack of consistent F&I funding, many installations manage these requirements through end-of-year funding.
- Some installations do not have a painting and protective coatings management plan. It is a low priority for buildings, because no manpower is available to conduct preventive maintenance.

The following are the survey responses to questions about whether the installations or design agents are investigating failures to determine if corrosion-related material deterioration is the cause:

- In general, installations are not investigating failures related to material deterioration; however, as they further investigate requirements to accomplish repairs, much of it was proven to be related to corrosion. For example, a roof collapse was identified as a functional mission failure (performance failure) that had to be repaired, but investigations indicated dry rot caused the failure.
- Other installation representatives mentioned that most failures are the result of poor construction practices and inadequate government construction agent supervision.

- Some installations indicated they are frequently in a reactive mode, repairing system failures and restoring service quickly; they simply do not have the time or resources to do such investigations.

- Design and engineering agents (e.g. USACE and NAVFAC) will investigate failures for facilities and systems as requested by installations. One such investigation resulted in the determination that coils in a barracks HVAC system were corroding and failing prematurely. It was determined that improper water treatment was causing the premature failure of the coils. This information was added to lessons learned for future reference.

Corrosion related to health and safety is more likely to elevate corrective actions. Pictured is a highly corroded sprinkler head.

TRAINING AND COMMUNICATION

CPC Training Assessment

Information obtained from the site visits to installations included a brief overview of the corrosion-related education and training that facility maintainers receive. To properly assess maintenance requirements associated with corrosion, the maintainer must have training that aligns with DoD guidance. Appropriate training in CPC matters can reinforce a plethora of skills in controlling corrosion. This expansion of knowledge and understanding of CPC matters is the foundation for correctly using criteria, technology, and good corrosion engineering practices.

Providing CPC-focused facilities and infrastructure training is essential for ensuring engineers, architects, technicians, and maintainers can focus on F&I CPC needs. The secondary target audience for training includes acquisition logisticians, contracts specialists, and program managers.

To ensure full coverage of the broad reach of CPC as defined in Title 10 USC, training topics must include the following general areas:

- Mold- and mildew-resistant coatings

- Cathodic protection principles, installation, and maintenance

- Reinforcing steel
- Applicable codes (ACI, American Society of Heating, Refrigerating, and Air-Conditioning Engineers [ASHRAE], etc.)
- Structural deterioration
- Wood deterioration
- Hexavalent chromium (Cr6+) issues and mitigation
- CPC features included in the design
- An understanding of what information is available in the WBDG and how to use the criteria (see Appendix C).

F&I training opportunities span the entire spectrum, from core training and education in their respective career fields to on-the-job training. Unfortunately, very few of these courses provide an in-depth view of CPC content.

The following is a partial list of available resources for F&I professionals to expand their CPC awareness:

- CorrDefense (www.corrdefense.org) presents laws, regulations, policies, technical library, and a supplier portal.
- CorrConnect (www.corrconnect.org) includes training videos, modules, and applications on demand.
- NACE has extensive CP training and certification programs. These courses vary from an online, asynchronous format to a classroom or seminar setting. D, CPO provides tuition support.
- The Society for Protective Coatings (formerly Steel Structures Painting Council) is heavily involved in infrastructure training and also has courses available in several convenient delivery methods. D, CPO provides tuition support.
- The Army Corps of Engineers Learning Center has the Proponent-Sponsored Engineer Corps Training (PROSPECT) program and provides job-related training through technical and professional courses to meet the unique needs of USACE and other government agencies.
- The Air Force Institute of Technology is the Air Force’s graduate school of engineering and management as well as its institution for technical professional continuing education.

- Several professional societies, such as the American Institute of Architects, the American Society of Civil Engineers (ASCE), and the ASHRAE provide F&I-focused CPC training. Topics include
  - the design and renovation of wood structures;
  - corrosion in steel reinforcing concrete structures;
  - corrosion prevention in construction fastening systems;
  - advanced moisture, mold, and building envelope workshop;
  - humidity control applications, control levels, and mold avoidance;
  - humidity control principles and applications; and
  - the fundamentals of water system design (for mechanical systems).

General Training Concerns and Trends

- F&I personnel at sites in the high ESI zones appear to have a better understanding of the corrosion challenges related to their more extreme environment than those located at sites in lower ESI zones. This expanded knowledge on CPC can be attributed to on-the-job training.
- Field personnel in construction offices would benefit from having access to F&I CPC training on the desktop to assist with design reviews, engineering solution determinations, and quality assurance actions.
- The FICE study team noted a great deal of interest from F&I personnel in additional CPC training.
- Unless the architects, engineers, and maintenance staff are aware of CPC technologies they cannot specify what is needed, nor can they effectively provide QA on contractor work.
- Sending F&I personnel to conferences or symposiums, such as the Lighting Symposium and the Snow Symposium, are good ways to learn about new technologies and a good way to obtain training resources.
- The Whole Building Design Guide hosts an extensive library of corrosion-related criteria, but it has no associated corrosion-related training. Engineers and architects are expected to use the site, but the absence of online or other CPC training is a major deficiency. Once this deficiency is corrected, the WBDG would better serve the professional and maintenance community.

Paint blistering on wall.

SPECIFIC TRAINING FEEDBACK

- A common theme at most installations is the lack of funding and time available to support training needs.
- An effective CPC training and education program must include short, to-the-point briefing packages that are available online and circulated to key HQ, field SRM and facility planners, and criteria managers to explain and define CPC and its role in the facilities lifecycle.
- To build better awareness, industry forums of DB contractors (to familiarize themselves with CPC technologies, opportunities, and requirements) will help emphasize the need to include good CPC technologies in construction.
- F&I professionals are well versed in their disciplines, but may not be knowledgeable of CPC until a specific need arises. When faced with facilities engineering issues, instead of obtaining CPC training, the F&I professionals often obtain the assistance they need from others in their organization, service SMEs (if known), or manufacturers' representatives.
- Many F&I professionals are not aware of available CPC F&I training because it is not well advertised or categorized. They would consider obtaining CPC training if they knew what was available. Many would prefer classroom training, which allows interaction with the instructors; face-to-face interaction provides a more enhanced learning experience as compared to web-based training. Because of busy schedules, many engineers would prefer that training not exceed 2 or 3 days. Many expressed an interest in a series of short training clips that provide general information and identify sources of additional information on the subject.
- CPC training could be combined with required training for design, construction and preventive maintenance, as it is done currently for several Army installations. Local corrosion issues are currently addressed at each site; however, the issue regarding "corrosion" across planning, design, acquisition, and SRM still needs to be addressed.

- Local training of engineers and technicians through sponsorship and partnerships with associations is a welcomed addition to professional growth.
- Membership in professional organizations allows access to training, resources, and conferences. Increasing the use of webinar and online education, particularly ASHRAE and ASCE, would benefit the staff.
- At several facilities, there was an interest in access to short F&I-focused training vignettes (approximately 10 minutes) that could be used for training during staff meetings.
- It is difficult to effectively reach shop personnel with training products, but solving the issue would help address corrosion-related issues.
- Several Air Force bases use NACE courses and certifications and leverage their online studies and instructional textbooks.
- There is no corrosion training or instruction on how to identify the root causes of corrosion-related deficiencies. Jobs are assigned to craftsmen; if a trend is identified, a request is placed for an engineering analysis.

Communications Assessment

Effective communication among F&I colleagues is necessary to expand the use of best practices, the latest technologies, and criteria and to assist with knowledge transfer within an aging and retirement-eligible workforce. Communication helps by spreading the word on what works (best practices), encouraging intelligent resource management, and sharing ideas on what corrosion technologies and practices work. The following are among the best communications practices from the field:

- Most projects are reviewed and coordinated by a committee of public works design and maintenance, safety, environmental, and security to ensure projects are fully coordinated before release.
- The AFCEC Reach Back Center posts technology developments.
- Having the contracting organization collocated with the designers and project managers has proved beneficial for processing and completing work requirements. One location found that having the shop's personnel collocated with the project engineers and designers improve the installation's SRM program.
- Sharing of information and practices with the neighboring Canadian government (primarily on radar systems) facilitated radar site repairs because their radar groups experienced similar failures.

- There is a need to reinvigorate the apprentice program to build the pipeline of next generation of craftsmen.

- The assignment of building managers provides for a first line of information contact and is a wise expenditure of resources with less extraneous work requests clogging the system.

- One base that includes both Army and Navy organizations has monthly team meetings during which they discuss and prioritize projects maximizing facilities utilization and resource management. This installation, although not considered a joint base, operates toward combined objectives. The primary challenge at this location is corrosion mitigation of many magazine doors.

- USACE leverages communities of practice (COPs) to communicate best practices or information to all facilities. There is also a supporting COP web application utilized to gain more information regarding new technologies. The website hosts discussion forums and phone conferences. Building code and local code amendments are discussed.

- One location found that networking with the same suppliers that are introducing new technologies has helped its program.

- One Air Force base found that leveraging best practice seminars or even simple email newsletters with best practices and most cost effective/best payback activities has helped. The base provides training on the latest products and technologies and cross-feeds information with industry.

Local standards in Guam call for sealing intake of chiller rooms to mitigate corrosion.

The study team found communications lacking in some aspects.

- Large numbers of F&I professionals, including those with corrosion expertise, are retirement eligible. There is a definite need to address training and know-ledge transfer before those employees retire. There is a lack of horizontal communications (base-to-base sharing of information). Effective communication facilitates knowledge transfer where best practices can be shared.
- Most F&I staff searched for information on the web in regards to CPC and technology.
- An emphasis must be made in the proactive approaches to knowledge sharing; formal COPs and web-based newsletters are excellent for spreading the word about corrosion.

GENERAL AREAS OF INQUIRY

The field-level representatives was asked to identify the five top areas for addressing expenditures or resources related corrosion and how corrosion-related deficiencies compete with other priorities for resources (funding and manpower).

On the question of SRM expenditures, the field responses emphasized the following:

- Water analysis and treatment programs are essential.
- Conducting preventative maintenance and inspections with follow-up repair work before it becomes a major problem.
- Replacing ductile iron with PVC in areas where lignite is present.
- Focused attention to preventative maintenance actions to ensure service life.
- Finding and installing alternatives to steam systems.

This corroded fire extinguishing system could be elevated as a safety priority.

On the topic of competition for corrosion-related resources, the field representatives provided the following input:

- Most believe corrosion-related deficiencies are not competitive with other priorities or resources, mostly because all maintenance is based on a functional versus a corrosion mission. Corrosion is usually included as a secondary issue. Safety, health, and failure effects push up the priority level.
- Many locations are driven by energy savings rather than by corrosion control.
- Requirements associated with environmental, ATFP, energy, and National Register of Historic Places programs increase maintenance costs. Sometimes, these requirements are antithetical to good corrosion practice.

FIELD-LEVEL SUMMARY

The F&I professionals surveyed by the FICE study team carefully considered the questions asked of them. Once they had a clear understanding about the definition of corrosion, they provided honest and thorough responses to the study team's questions. The responses correspond to the unique environment of each installation of tools, and were tempered by available resources and levels of experience.

The effect corrosion has on readiness and day-to-day operations was evident at every installation. While most responses are location-specific, they also are indicative of the across-the-board issues that most installations experience. Among the universal CPC challenges identified (issues that cross service, installation mission, and geographic location) were problems with acquisition specifications, contracting, awareness, use of criteria, data management, training, and communication.

Chapter 7

Summary and Conclusions

D, CPO conducted an extensive investigation and analysis of how corrosion affects facilities and infrastructure within the Department of Defense. The study team found that DoD F&I management varies by respective military service and installation mission, specific environments, and available F&I personnel.

While management of F&I is fairly decentralized (each installation carries the management authority to support specific mission requirements), operations are governed by DoD, the military services, and regional and local policies and guidance. The local management and execution of sustainment, restoration, and modernization, however, is the responsibility of each public works officer, department of public works, or base civil engineer.

Facilities professionals who are responsible for the management and oversight of DoD facilities and infrastructure, including the DUSD(I&E), each military service, the services' subordinate commands, and a multitude of supporting elements, were involved in responding to this study.

The response to NDAA requirements and objectives language are located in the following chapters:

- ✓ Chapter 1 presented the sampling technique of the FICE study team. Sampled facilities were representative by facility type, military department, and facility age.
- ✓ Chapter 3 presented the key drivers of corrosion-related costs.
- ✓ Chapter 4 presented the study team's assessment of a planned facility construction programs.
- ✓ Chapter 5 identified corrosion prevention and mitigation technologies that may be integrated into future facilities.
- ✓ Chapter 6 outlined, at a high level, service-specific facility engineering processes as they relate to corrosion prevention and mitigation.

The underlying challenges that each military service faces in the sustainment of F&I are fairly similar. Installations must address CPC adequately within the constraints under which they operate, but opportunities for improvement exist.

MAJOR FINDINGS

Defining Corrosion

Four key dimensions provided context for the FICE study:

- Planning and programming
- Acquisition (design and construction)
- Sustainment (operations and maintenance)
- Technology identification and implementation.

In each of these dimensions, F&I personnel are faced with corrosion-related decisions that affect material performance and system service life. Thus, factors that influence the corrosion-related decision process are adequate knowledge of corrosion policies and criteria and beneficial technologies, awareness of best practices, and advocacy for implementation.

It is important to note that most F&I personnel are facilities-centric or focused on a specific trade, engineering discipline, or management process; they are not necessarily focused on corrosion. In the course of their duties, they experience corrosion that affects the longevity or performance of facility components. They may accept corrosion as normal wear, not knowing that corrosion prevention criteria or mitigation technologies are available. Of course, personnel at installations in high ESI zones are more proactive in preventing corrosion because the high corrosivity and immediate effect of corrosion damage require a more conscientious and lasting course of action.

F&I-specific corrosion prevention and mitigation measures are in place within relevant focus areas, including policies, design and construction criteria, technology, MILCON, and SRM programs. Despite the extensive corrosion-related language in regulations, instructions, policies, and guidance, the FICE study team noted instances when field-level implementation of those policies and guidance was not well executed. The study team also observed that the lack of focus on corrosion issues was related in part to the perception that corrosion was viewed only as rust and the oxidation of metals, rather than the more comprehensive definition outlined in congressional language. That lack of awareness did not diminish the focus of the F&I community on the compelling need to address material degradation. Increasing the community's knowledge of the fundamentals of corrosion prevention and availability of CPC technologies would improve decision making at all stages of facility management.

This finding highlights the need for further expansion of communications and outreach by the corrosion community to better educate the F&I community.

Communications

Each military department has clear and direct channels of communication for their respective installations. This establishes a chain of command in which CPC guidance and policies are issued from higher headquarters. Individual installations provide feedback to headquarters regarding the implementation and effectiveness of this guidance.

The study team found CPC communications was limited between installations either within a service or across services. This limits the sharing of valuable and useful information on CPC-related technologies, best practices, methods, and processes. A few F&I professionals reach out to similar installations with similar mission objectives; more often, installations consider themselves unique, with challenges that differ—in both mission and objectives—from other sites.

From a CPC perspective there is significant commonality across sites. Discussions with participating F&I personnel suggested a centralized forum for discussion of challenges, lessons learned, best practices, and policy would be beneficial, not only to address these topics, but also to foster collaboration.

Training

The study team found that CPC training is minimal because of funding constraints and the lack of available coursework with direct application to the areas of responsibility. Further projecting the need for more CPC training is the high personnel turnover (the result of an aging workforce) with limited knowledge transfer results in lost corrosion-specific expertise. Younger and newer personnel have minimal corrosion-related experience or are not aware of corrosion prevention choices.

Because funding is limited for training and education of personnel at all levels, higher priority training requirements compete for or displace the training resources required for corrosion training.

Training and education provides the knowledge base to make better corrosion-related decisions and promote corrosion prevention advocacy. Several installations indicated that effective corrosion training and education needed to be low cost, a reasonable time length, and have direct application to their area of responsibility.

Joint Bases

The F&I maintenance processes for joint bases, including CPC, are well established and working; however, installations continue to adjust and transition because residual contracts and contract support are in place before the transition to a joint bases. The differences in acquisition processes between the tenant organizations and the host military services also factor into the challenges of CPC management.

The policies that are followed reflect the primary military service that is facilitating the installation, but there are instances when two sets of guidelines are followed. Another FICE study team observation involved the confusion over which criteria to follow (tenant or host), particularly in regards to direct mission facility needs.

What is clear is the necessity for the deliberate participation of all stakeholders toward meeting the objectives- and mission-related facility requirements. Organizational priorities are addressed as a joint team, and then executed based on resources and priority. The beneficial results from joint basing with respect to CPC will not be immediately realized as the transition is still ongoing.

Installation Realignment

Base realignment has resulted in the addition of new tenants on existing installations. In some cases, the host installations have not been given additional resources to support the increased sustainment requirements. This will limit CPC efforts because F&I staff shift from a proactive management of materials degradation and reactively address the most immediate health and safety concerns. Deferred maintenance of facilities and infrastructure will inevitably reach a threshold where material degradation will become so bad that total recapitalization is necessary.

Competing Priorities

Some installation responses spoke unfavorably about the need to become Leadership in Energy and Environmental Design (LEED) certified because the cost to obtain and maintain the certification strains the ability to shift resources to meet other priorities. The resources spent for certification are not available for CPC efforts and tradeoff decisions needs to be made. ATFP, the National Historic Preservation Act of 1966, and environmental program requirements similarly reduce available funding otherwise slated for high-priority SRM deficiency (including corrosion degradation) correction.

Policy

CPC is addressed extensively in various policies and criteria. Some policies and guidance are not being followed or are not being well executed at some installations. Awareness is less than optimal at the installation and design agent level, and few personnel fully understand the *Whole Building Design Guide* and the significant CPC-related criteria (UFCs and UFGSs) contained within it.

There must be a balance between standardization of policies across DoD and the flexibility in the application of those policies with respect to each installation's challenges and requirements. In some instances, standard policies have negatively affected CPC; other locations rely on the knowledge of general commercial practice and are unaware of DoD or military service CPC guidance. Increasing policy awareness can be accomplished through the chain of command and as part of training modules.

Acquisition

The best-performing contracting groups, from a CPC perspective, are staffed as part of the F&I organization; thus ensuring contracting personnel are knowledgeable regarding facilities construction and maintenance as well as corrosion. Achieving desirable CPC outcomes is more of a challenge at installations where contracting personnel are unfamiliar with facilities or installations.

Inconsistencies in the use of the WBDG criteria for design and construction can result in a deficiency to contract for DoD-mandated levels of standardization and quality. This is a potential cost problem that includes questionable identification of and contracting for CPC requirements.

Some installations indicated that mandatory contracting targets, such as contract laws and mandated small business set-aside programs (8[a], HUBZone, SDVOSB, etc.), hinder their ability to obtain the best-qualified CPC contractor and solution. Installations prefer a centrally managed, multiple-use or multi-purpose contracting vehicle for expediency of project execution.

For design-build projects, the contractor has greater flexibility in using newer, better technologies to meet the performance requirements of the contract. In many cases, however, the contractors shy away from offering CPC technologies that would exceed the minimum performance requirements—even if the technologies would provide a lifecycle cost advantage—because these technologies cost more initially and increase project costs, putting the contractor at a competitive disadvantage. Technical selection factors in the source selection process typically do not include specific CPC considerations.

Where CPC is not addressed in the design phase, it is difficult to correct in the contracting phase (normally increases costs). Possible improvements include educating design agents on CPC and lifecycle criteria, along with improving construction management awareness of CPC.

Technology

The transition of F&I technology remains a challenge, given the lack of resources and the need to ensure only the most mature and reliable technologies are employed. Among the challenges integrating new technologies are initial-cost versus long-term costs, proven reliability, low maintenance, and acceptance and familiarization by the facilities community.

Field personnel are also either not aware of new developments and technologies or neglect to apply the new criteria that would reduce the effect of corrosion on facilities. Technology development and implementation is highly reliant on commercial practice and is not always focused on unique DoD needs. Similarly, UFCs do not always address the best CPC practice in unique environments, potentially shortening the effective lifecycle of a facility. The WBDG also significantly lags in the adoption of criteria for new technology, delaying the benefits many facilities may glean.

The collaborative efforts of DoD, the military services, industry, and the academic community continue to be an essential “force multiplier” to ensuring the latest technologies are assessed and transitioned into an appropriate format for use by F&I professionals. Most personnel interviewed by the FICE study team were more comfortable with a higher headquarters requiring and directing the implementation of new technologies, rather than having a choice of implementation. Possible improvements include continued work on transitioning of new technologies into criteria, review of technologies and directed use where economically beneficial, and review of current technologies for cost and ROI advantages.

MILCON and SRM

An assessment of a planned facility construction program was requested, and the D, CPO selected P-65271 Hospital Replacement, Naval Hospital Guam. Guam is one of the most severe environments, so it was appropriate to explore the culmination of CPC considerations (policies, technology, cost drivers) in the planning of the program. The assessment results show that appropriate CPC planning and decisions made in the development of this project will directly enhance the facilities’ lifecycle and is a good model of a military construction project from a CPC perspective.

Of concern for all SRM and MILCON is quality assurance (government) and quality control (contractor) to ensure construction is consistent with the contract documents, and includes CPC aspects of project execution. Lack of CPC-trained personnel and available resources directly affect the quality of completed construction. The study team found that providing greater CPC awareness for BOS contractors providing SRM support at DoD installations would extend the facilities’ service life. The team also observed how the adherence to criteria in the UFGS and correct UFGS application usually results in CPC being included on projects.

While design agents and design teams are knowledgeable of the UFGSs and UFCs, they may be marginally aware of CPC requirements and the benefits of material selection. Improving design agent CPC awareness will increase the knowledge base and improve corrosion-related decision making.

Management Systems

Maintenance management systems in use by the military services lack the coding necessary to identify corrosion-related requirements. Having this information would assist in resourcing decisions, maintenance prioritization, identification of technology gaps, and maintenance backlog categorization.

Service maintenance management information systems are of varying complexity and usefulness, although none of them address military service–wide SRM management needs. Despite the use of condition assessment programs and maintenance management systems over the years, the military services have recognized the difficulties in accurately and consistently measuring and reporting the condition and backlog of SRM needs against their facilities.

Specifically, GFEBS uses Systems Applications and Products in Data Processing (SAP) software, a commercial off-the-shelf (COTS) enterprise resource planning (ERP) solution. Because of the initial intent of the system's financial design, the overall system lacks many of the easy-to-use tracking mechanisms that are needed by the DPW to monitor, track, and prioritize day-to-day SRM projects. Many installations have created their own Excel-based spreadsheets to more easily manage their SRM workload. The older tracking systems used by the installations had been adapted to provide the needed monitoring/tracking information. The new system does not provide the easy access to determine trends in problems, which could be helpful for the DPW.

In the past, each military service employed separate processes of varying scope and complexity to manage SRM needs. Lack of resources, especially the loss of the journeyman experts who periodically looked at every structure and facility, has made this key information unavailable to facilities managers and higher headquarters. As a result, resourcing decisions and F&I service life are impaired.

A missing element in workflow management systems is a CPC metric to determine if maintenance actions are adequately addressing corrosion degradation. Most maintenance actions and requirements are not corrosion-centric, but corrosion can be a root cause or a contributing factor in the need for action. Other maintenance can be preventive in nature and not corrective. Because of the complexity of the maintenance requirement, information technology–based workflow systems cannot distinguish between CPC and non-CPC work.

Another challenge is backlog or requirements that are not funded and, therefore, deferred. The effect of deferred maintenance is increased degradation and greater costs, because more action may be required to correct the additional damage. Backlog adds to funding requirements that may not have been anticipated in the prior year planning and budgeting. This creates a scenario in which maintenance requirements quickly outgrow available funding, and it feeds a continuous cycle of increasing deferred maintenance levels.

Installations have learned to prioritize and couple the “worst first” with a scaled importance to the military mission; but the backlog is never cleared. CPC plays a part in optimizing facility service life and component performance. Thus, applying consistent CPC processes provides long-term benefits that initially may not be realized.

CONCLUSION

The continued corrosion degradation of F&I, factored with a high operating tempo and constraints on resources, will negatively affect the F&I community’s ability to provide mission-ready support capabilities for DoD. The military services are addressing CPC within their particular operational constraints. Areas of immediate concern that need improvement include training, communications, contracting, contract execution, new technology implementation, and data collection and management.

While not specific topics of this study, it should be noted that both Base Closure and Realignment and sequestration will have a bearing on corrosion impacts for DoD Facilities and Infrastructure. Closure of aging facilities will reduce associated corrosion-related sustainment costs. Sequestration will result in increasing levels of deferred maintenance and consequently result in higher levels of corrosion damage which will have negative impacts on cost and mission readiness.

Appendix A
Key Participants

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9. James Tran, LMI
10. Nick Silver, SAIC
11. Jillian Robbins, LMI
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13. Larry Lee, Chief of Staff, CPO
14. Susan Louscher, University of Akron
15. William Abbott, Battelle Corporation

Appendix B
Policy and Guidance Summary

Policy, guidance, or regulation	Title	Relevance	Applicability
Department of Defense			
CJCSI 3170.01F (1 May 2007)	*Joint Capabilities Integration and Development System*	Establishes the policies and procedures of the Joint Capabilities Integration and Development System (JCIDS). Supports Chairman and the JROC in identifying, assessing, and prioritizing joint military capabilities as specified in Title 10 USC.	Multiple references to Facilities in support of Joint Capabilities and focused on meeting required operational requirements. “Facilities” defined in the context of DOTMLPF and associated references.
JCIDS Manual 19 (January 2012)	*Manual for the Operation of the Joint Capabilities Integration and Development System*	Provides guidelines and procedures for operation of the JCIDS along with interactions with several other departmental processes to facilitate the timely and cost effective development of capability solutions for the warfighter.	Manual defines facilities in the context of DOTMLPF-P as Real property consisting of one or more of the following: buildings, structures, utility systems, associated roads and other pavements, and underlying land. Key facilities are defined as command installations and industrial facilities of primary importance to the support of military operations or military production programs. A key facilities list is prepared under the policy direction of the Joint Chiefs of Staff. Further discusses facilities in the context of closing capabilities gaps.
DODD 5000.01 (20 November 2007)	*The Defense Acquisition System*	Establishes framework, responsibilities, and requirement for the defense acquisition management.	ACAT program acquisition guidance; CPC must be considered; requires the use of the Federal Acquisition System.
DODI 5000.02 (8 December 2008)	*Operation of the Defense Acquisition System*	Provides guidance for the operation of the defense acquisition management.	CPC strategy required for reduction of TOC and CPC planning; requires facilities-related capability analysis in support of ACAT programs.
DODD 4270.5 (12 February 2005)	*Military Construction*	Establishes policies, authorities, and responsibilities for the military construction program.	Requires the use of criteria to the greatest extent possible for planning, design, and construction of facilities. Applies to MILCON and SRM.

Policy, guidance, or regulation	Title	Relevance	Applicability
DODI 5000.67 (1 February 2010)	*Prevention and Mitigation of Corrosion on Military Equipment and Infrastructure*	Establishes OSD CPC policy for military equipment and infrastructure and provides implementation guidance for 10 USC Sect. 2228.	Provides guidance for CPC in facilities and infrastructure program management.
USD(AT&L) Memo (2002)	*Department of Defense Unified Facilities Criteria*	Identifies MIL-STD-3007 as the guidance for developing UFCs and UFGSs and requires use of UFCs and UFGSs for planning, design, construction, sustainment, restoration, and modernization of facilities.	UFCs and UFGSs have extensive CPC coverage. See Appendix C for details.
USD (AT&L) Memo (2003)	*Corrosion Prevention and Control*	DoD direction to use best practices and best-value decisions in CPC for infrastructure acquisition, sustainment, and utilization.	CPC to be considered early in the design process; announces the development of a CPC planning guidebook to include infrastructure.
DUSD(I&E) Memo (2005)	*Facility Corrosion Prevention and Control*	Directs that current CPC measures and technologies be incorporated into facilities acquisition and maintenance.	Initiated review of F&I CPC program and military departments directed to review for CPC inclusion.
D, CPO Guidebook (2007)	*Corrosion Prevention and Control Planning Guidebook*, Spiral 3	Provides guidance for CPC planning.	Provides detailed insights into CPC for F&I.
FAR and DFARS	FAR 36, 52, etc.	Provides FAR guidance for facilities.	Construction and architect engineer contracts and solicitation provisions and contract clauses for F&I.
Criteria	UFC, UFGS, PTS	See Appendix XX, WBDG database search and summary.	Provides a broad range of in depth standards, practices, and material requirements for CPC-related facilities and infrastructure procurement, SRM and construction.

Policy, guidance, or regulation	Title	Relevance	Applicability
Life Cycle Sustainment Plan (10 August 2011) Version 1.0	*Life Cycle Sustainment Plan:* Sample Outline	The Life-Cycle Sustainment Plan (LCSP) is the program's primary management tool to satisfy the warfighter's sustainment requirements through the delivery of a product support package. Development of a life-cycle product support strategy and plan are critical steps in the delivery of the product support package. The LCSP remains an active management tool throughout the operations and sustainment of the system, and the program must continually update the LCSP to ensure sustainment performance satisfies the warfighter's needs.	Provides reminders to the program manager of the ACAT program to address corrosion and F&I requirements.
Department of the Army			
AR 700-127 (29 April 2009)	*Integrated Logistics Support*	Policy establishes requirement for ILS in support of Army materiel implementing DODD 5000.01 and DODI 5000.02.	Directs that CPC technical guidance and support be provided to the field Commands; directs that ILS design influence parameters be included for corrosion. Requires that appropriate studies be provided in support of new weapons systems.
AR 750-59 (9 January 2006)	*Army Corrosion Prevention and Control Program*	Policy defines all areas where corrosion prevention and control should be considered throughout the life cycle.	Addresses CPC in the context of facilities. Defers coverage for F&I CPC to other F&I-related regulations, including TM 5-811-7 (superseded by UFC 3-570-02A).
AR 70-1 (22 August 2011)	*Army Acquisition Policy*	Implements DODD 5000.01 and DODI 5000.02 and defines the regulation's applicability.	Requires that program requirements for CPC be established and implement a system CPC within SE. Requires designation of R&R for Army CCPE. Requires inclusion of F&I in acquisition program.
AR 420-1 (28 March 2009)	*Army Facilities Management*	Addresses the management of Army facilities, including public works, housing, facilities operations and management, master planning, utilities, and energy management, as well as fire and emergency services.	Establishes ACSIM responsibility for CPC management, including corrosion control design guidance and publications, implementation of an extensively defined CPC F&I program explained in Section VI of the documents.

Policy, guidance, or regulation	Title	Relevance	Applicability
DA PAM 750-1 (2 February 2007)	*Commander's Maintenance Handbook* (Maintenance of Supplies and Equipment)	Discusses wide spectrum of maintenance topics required for day-to-day operations. Delineates applicability of guidance and assistance in understanding how to achieve the requirements of the Army maintenance standard.	References AR 750-59 and discusses evaluation of F&I in support of mission. Chapter 2 states: "Maintenance facilities. These structures are significant maintenance enablers and centers of production to ensure that the Army Maintenance Standard and equipment readiness standards are achieved. Commanders should work closely with garrison officials to ensure that maintenance buildings, hardstands, sheds, utilities, and waste and environmental systems are properly maintained and functional, as these assets can contribute to safe and efficient maintenance operations."
Technical manuals (20 manuals; dates vary)	The manuals address a broad range of F&I-related design, engineering, and problem solving; all include references to CPC.	Topics include waterfront facilities, preventive maintenance, child development centers, electrical (interior and exterior), commissioning of systems, etc.	For more details, see http://armypubs.army.mil/eng/.
Public works technical bulletins (PWTBs) (Dates vary)	25 PWTBs that address a variety of technical issues related to public works management, including references to CPC.	Topics include issues related to utilities, environmental, range management, sewer system analysis, etc.	For more details, see http://www.wbdg.org/ccb/browse_cat.php?c=215.

Policy, guidance, or regulation	Title	Relevance	Applicability
Department of the Navy			
SECNAVINST 5000.2e (September 2011)	*Implementation and Operation of the Defense Acquisition System and the Joint Capabilities Integration and Development System*	Establishes ACAT program management framework and guidance for DON.	Navy ACAT program guidance; identifies NAVFAC R&R in support of ACAT programs, including SE/ILS support. While CPC and F&I are not directly linked, good engineering practice includes considerations for CPC-related requirements (coatings, steel selections, mold-resistant materials, etc.).
OPNAVINST 4790.2j (February 2005)	*Naval Aviation Maintenance Program* (NAMO)	Sets policy and establishes responsibility for the maintenance of U.S. Navy aviation assets. The objective of the instruction is to meet safety and readiness standards through the optimization of several areas, including facilities and protection of the system from corrosive elements.	While the instruction does not take the discussion of facilities and corrosion further, the message is clear; optimal performance is required for the system to meet standards. For a supporting facility to accomplish that task, it must be managed consistent with good engineering and maintenance practices, including CPC.
OPNAVINST 4790.15E (29 July 2011)	*Aircraft Launch and Recovery Equipment Maintenance Program* (ALREMP)	Sets policy and establishes responsibility for the maintenance of Navy aviation assets. The objective of the instruction is to meet safety and readiness standards through the optimization of several areas, including facilities and protection of the system from corrosive elements.	While the instruction does not take the discussion of facilities and corrosion further, the message is clear; optimal performance is required for the system to meet standards. For a supporting facility to accomplish that task, it must be managed consistent with good engineering and maintenance practices, including CPC. The instruction includes extensive aviation-specific corrosion-related guidance.
OPNAVINST 5100.23G (30 December 2005)	*Navy Safety and Occupational Health* (SOH) *Guide*	Provides SOH guidance and requirements for Navy.	Provides requirements for corrosion associated with construction and the use of certain materials.
OPNAVINST 5450.34B (April 2012)	*Mission, Functions, and Tasks of Naval Facilities Engineering Command*	Defines NAVFAC SYSCOM R&R, including F&I and corrosion functions.	Discusses R&R responsibilities for F&I, corrosion, cathodic protection, and SME access.

Policy, guidance, or regulation	Title	Relevance	Applicability
OPNAVINST 11010.20G (2010)	*Facilities Projects Manual*	Defines project authorities and limitations, guidance on the classification, preparation, submission, review, approval, and reporting of facilities projects at Navy shore activities, including MILCON and SRM projects. Requires use of current design criteria.	Addresses cathodic protection for facilities and infrastructure.
NAVFAC Instruction 7040.5G (20 September 2011)	*Naval Facilities Engineering Command Products and Services*	Provides detailed descriptions by business line of types of products and services available from NAVFAC, along with the associated funding rules.	This document describes published NAVFAC's products and services. See Enclosure 1 for corrosion and cathodic protection descriptions (in lines H12, H13, H23, and N35). The last two tabs provide work induction business rules and descriptions.
NAVFAC Instruction 11013.39B (14 September 2000)	*Operations and Maintenance Support* (OMSI) *for Facility Projects*	Requires submission of documentation associated with the construction and as-built conditions of a completed project.	Clearly defines the extent of F&I project documentation to be submitted to the PWD/FEC to ensure appropriate as-built materials and drawings are available during sustainment. Corrosion is not mentioned specifically, but details associated with coatings, cathodic protection, and materials used would be included in the OMSI package.
NAVFAC business management system processes (Dates vary)	Various, such as ◆ *Acquisition Planning*, ◆ *Project Initiation*, ◆ Special Project Development, ◆ *MILCON*, ◆ *Cathodic Protection*, ◆ *Design-Build*, and ◆ *Design Bid Build*	These processes define how projects are developed, referencing OPNAVINST 11010.20GF and the WBDG and *NAVFAC Design Build Master* for use of the appropriate criteria based on industry standards (see Appendix C for information about the WBDG database) as well as requesting SME assistance, such as in the area of cathodic protection.	Provides detailed steps for NAVFAC personnel at all levels of the organization to accomplish specific tasks in a standardized, streamlined, and approved approach.
Engineer Construction Bulletin 2008-03 (2008)	*Acceptance Testing of Critical Systems*	Addresses CPC-related government quality assurance requirements for F&I.	Provides multiple places where QA for F&I should be performed, such as verification of the presence of condensing unit, heat pump, and other HVAC component anticorrosion coatings.

Policy, guidance, or regulation	Title	Relevance	Applicability
NAVFAC P-307 (December 2009)	*Management of Weight Handling Equipment*	Provides guidance and standard practice for the management, maintenance, inspection, testing certification, alteration, repair, and operation of WHE at Navy shore installations.	Note that while it does not directly address CPC in facilities and infrastructure, it does address CPC as it relates to weight-handling equipment, such as cranes in shipyards and dry docks.
NAVFAC maintenance and operations manuals 25 manuals (Dates vary)	NAVFAC has in place a large body of work in the form of maintenance and operations (M&O) manuals to ensure, at various levels, standardized technical processes and procedures are available and followed in the form of a guide.	The M&O manuals are often linked with criteria and content on the WBDG (www.wbdg.org). Topics include corrosion control, wood protection, wood inspection, pest control, weed control, historic structures preservation, hyperbaric facilities, solar heating systems, mooring maintenance, petroleum fuel facilities, waterfront facilities, etc.	For example, the MO-307 (Sept. 1992) provides technical guidance for both naval and civilian personnel in identifying existing or potential corrosion problems, determining the proper corrective actions, and implementing the corrective actions. Provides extensive information regarding corrosion control (introduction), corrosion control policy, forms and mechanisms of corrosion, methods of corrosion control, common corrosion control problems and their remedies, corrosion control utilizing coatings, corrosion-resistant metals, cathodic protection, identification, and characterization of corrosion problems.
NAVFAC P-publications 3 publications	NAVFAC publications (handbooks) are provided to establish official Navy and Naval Facilities Engineering Command guidance on specific topics.	Handbook topics that include F&I CPC guidance include economic analysis, design and engineering lessons learned, and PWD management guidance.	Handbooks address requirements to provide CPC facilities in support of aircraft maintenance, to PWD operations, and lessons learned for F&I designs.
Marianas Navy and Marine Corps Design and Construction Standards (September 2011)	*Marianas Navy and Marine Corps Design and Construction Standards*	This document focuses on location-specific design and construction standards, including CPC risks for F&I.	Leverages available knowledge, UFCs/UFGSs, and other resources to provide a one-stop knowledge base for Guam design, engineering and construction requirements. Note: similar documents can be found on www.wbdg.org.

Policy, guidance, or regulation	Title	Relevance	Applicability
Marine Corps			
Note: MCICOM follows NAVFAC guidance, including ECBs and WBDG criteria.			
MCO P5090.2A	*Environmental Compliance and Protection Manual*	Establishes Marine Corps policies and responsibilities for compliance with environmental statutes and regulations, as well as the management of Marine Corps environmental programs.	Includes guidance regarding corrosion control and prevention on certain real property assets.
MCO P11000.12C	*Real Property Facilities Manual, Volume II, Facilities Planning and Programing*	Provides guidance and instructions relating to the Marine Corps Facilities Planning and Programming System.	Includes procedures to plan and program facilities requirements for activities under the command of the Commandant of the Marine Corps.
MCO P11000.7C	*Real Property Facilities Manual, Volume III, Facilities Maintenance Management*	Provides guidance and instructions concerning real property facilities maintenance management including controlled inspection programs.	Includes policies, guidance, and instructions that pertain primarily to real property facilities maintenance management and certain services categorized as operations.
MCO P11000.5G	*Real Property Facilities Manual, Volume IV, Facilities Projects Manual*	Provides policy and guidance for the preparation, submission, review, approval, and reporting of facilities projects at Marine Corps installations.	While CPC is not specifically mentioned, it clear states the policy and guidance for restoration and modernization for repair projects. In the sample DD Form 1391 in Appendix D, a corroded steel bulkhead is used at the example description of proposed construction.
Department of the Air Force			
AFPD 32-10 (4 March 2010)	*Civil Engineering; Installations and Facilities*	Establishes for Air Force installations, implementing several DODDs and DODIs and delineates applicability of the AFPD. Addresses F&I SRM resourcing and management. Identifies authorities and responsibilities of various levels of the chain of command.	CPC is not specifically mentioned; it clearly requires life-cost considerations and investment level determinations and making assessments on assets relative to mission support. All of these actions would require consideration of CPC.
Air Force Instruction 21-101 (26 July 2010) (ANG: 22 April 2011)	*Aircraft and Equipment Maintenance Management*	Assigns authorities and responsibilities, including specific actions to be taken to achieve aircraft and equipment maintenance management in support of mission.	Requires associated facilities to function in support of aviation CPC and aircraft and equipment maintenance management.

Policy, guidance, or regulation	Title	Relevance	Applicability
ANGI 21-105 (20 September 2002)	*Maintenance: Corrosion Control, Non-Destructive Inspection, and Oil Analysis Program*	Defines and incorporates significant changes in corrosion prevention and control and related corrosion inspections activities. Assigns responsibilities for corrosion inspection, supervised by the aircraft structural work center. Defines the responsibilities of the unit corrosion manager and establishes a "proactive role" in the organization's corrosion prevention program.	Facilities are briefly discussed in support of mission. Corrosion is extensively discussed. Requires funding be requested for facilities in support of a corrosion control program.
PACAFI 21-105 (26 November 2003 [Current 20 November 2008])	*Maintenance: Aerospace Fabrication Maintenance*	Provides guidance and direction necessary to develop an effective aircraft metals technology program, non-destructive inspection program, aircraft structural maintenance program, and survival equipment program.	Ensures adequate facilities, equipment, manpower, material and funding are available to support a sound corrosion prevention and control program.
AETC Instruction 21-106 (26 March 2012)	Maintenance: Corrosion Control	Establishes AETC corrosion control guidance and procedures and assigns responsibilities for implementing and maintaining an effective corrosion control program for aircraft; aerospace ground equipment (AGE); electronic equipment; support vehicles; communications, electronics, and meteorological (CEM) equipment; and all other end items relative to the functions of AETC.	The maintenance group commander is directed to monitor facilities to ensure they are adequate to meet mission requirements and to ensure proper levels of equipment, work force and material funding is available to support a sound corrosion control program. Identifies minimum facilities required to accomplish mission.

Policy, guidance, or regulation	Title	Relevance	Applicability
AFI 32-1001 (1 September 2005)	*Civil Engineering: Operations Management*	Implements AFPD 32-10, *Installations and Facilities*. It provides the directive requirements for the operations management of civil engineering. It establishes a civil engineer worldwide baseline set of definitions, operations process descriptions, and organizational guidance, which applies to the objective operations flight organization for both groups and squadrons (civil engineer groups should use the appropriate organizational equivalent to flight used in this AFI).	Mentions responsibilities in section 2.1.1 for 3E0XX AFS, which includes cathodic protection.
AFI 32-1054 (1 March 2000)	*Civil Engineer: Corrosion Control*	Provides responsibilities and general requirements for the corrosion control program at major commands and bases. It applies to personnel involved in design, construction, acquisition, operations, and maintenance of real property assets and installed equipment at installations and facilities. It implements EPA, DOT, OSHA regulations, and guidelines pertaining to corrosion control activities and follows selected industry standards published by NACE International (formerly National Association of Corrosion Engineers).	This instruction implements AFPD 32-10, *Installations and Facilities*. It provides responsibilities and general requirements for the corrosion control program at major commands and bases.

Policy, guidance, or regulation	Title	Relevance	Applicability
AFI 32-1065 (1 October 1998)	*Civil Engineering: Grounding Systems*	Assigns maintenance responsibilities and requirements for electrical grounding systems on Air Force installations. This includes systems for equipment grounding, lightning protection, and static protection. This instruction also implements the maintenance requirements of DoD 6055.9-STD, *Ammunition Explosives Safety Standards*, Chapter 7, "Lightning Protection" (August 1997), for potentially hazardous explosives facilities.	Multiple references to cathodic protection and corrosion for pipelines, electrical systems where grounding is required.
AFI 32-1084 (20 April 2012)	*Civil Engineering: Facility Requirements*	Provides guidance for determining space allocations for Air Force facilities and may be used to program new facilities or evaluate existing spaces. Provides facility space allowance guidance by category code (CATCODE). These criteria are used in assigning occupancy of existing facilities and in programming new facilities.	Multiple references to cathodic protection and corrosion. Identifies facility categories where corrosion control facilities should be planned and programmed such as CC hangars, maintenance facilities, etc.
AFI 63-101 (3 August 2011)	*Acquisition: Acquisition and Sustainment Life Cycle Management*	Establishes the integrated lifecycle management (ILCM) guidelines, policies and procedures for Air Force personnel who develop, review, approve, or manage systems, subsystems, end-items and services (referred to as programs throughout this document) procured under DODI 5000.02. This instruction also implements the policies in DODD 5000.01, DODI 5000.02, OMB Circular A-11, and related guidance.	Multiple references to corrosion and facilities. Corrosion prevention and control planning is covered in section 2.68. Identifies the Air Force CCPE as the senior CCP enterprise official.

Policy, guidance, or regulation	Title	Relevance	Applicability
AMCI 21-119 (30 December 2006)	*Maintenance: Corrosion Control Program*	Establishes Air Mobility Command (AMC) standards, procedures, and policies for aircraft and aerospace ground equipment (AGE) corrosion abatement programs. It provides guidance and direction to develop an effective corrosion prevention, treatment, and management program. Also delineates organizational applicability.	Ensure proper facilities, training, materials, and personnel are dedicated to combating corrosion is one of the responsibilities of the Maintenance Group Commander.
AFMCI 21-117 (12 October 2010)	*Maintenance: Corrosion Control and Prevention Program and Marking of Aerospace Equipment*	Provides policy, objectives and assigns responsibilities for implementing and maintaining an effective corrosion prevention and control program for aerospace systems, equipment, and components in AFMC. Specifies responsibilities performed at each level of command and implements guidance presented in AFI 21-105, *Air Force Occupational, Safety, and Health*, 48 and 91 series instructions, technical orders (TO) 1-1-691, *Aircraft Weapons Systems Cleaning and Corrosion Control*, and 1-1-689, *Avionics Cleaning and Corrosion Prevention/Controls*, command instructions, and the specific aircraft (23 TOs).	One of the responsibilities of the Maintenance Group Commander (MXG/CC)/Product Director is to ensure that adequate facilities, equipment, manpower, material and funding are available to support a sound corrosion prevention and control program as well as adequate wash rack facilities on a year round basis.
ETL 01-1 (11 October 2001)	*Reliability and Maintainability* (R&M) *Design Checklist*	Provides a generic design checklist to be used in developing functional, reliable, and maintainable facilities constructed by or for the Air Force. The checklist will help personnel in charge of planning, designing, constructing, operating, and maintaining Air Force real property. Serves as a convenient guide for the review of plans and specifications for construction projects.	Includes references to corrosion design requirements such as underground electrical outer jacket, flashing for roof-mounted equipment, corrosion-resistant material selections, etc.

Policy, guidance, or regulation	Title	Relevance	Applicability
Air Force Handbook 32-1290(I)' MIL-HDBK-1136/1 (1 February 1999)	*Cathodic Field Testing*	Summarizes actions to be taken in operating and maintaining various cathodic protection systems in use at military installations. Considerable instruction is also provided on conducting the testing procedures necessary for ensuring proper functioning of the systems. Meant primarily to aid the craftsman at unit level in performing their duties and responsibilities.	Delineates maintenance actions for cathodic protection in F&I affected areas.
Air Force manuals 3 manuals	◆ *Facilities Engineering Electrical Interior Facilities* ◆ *Maintenance of Trackage* ◆ *Explosive Safety Standards*	Provides guidance for the maintenance and repair of various F&I systems.	Each document addresses F&I corrosion-related issues.
Air Force guides (31 May 2004) 2 guides	*Air Force Munitions Facilities Standards Guide* (Vols. 1 and 2)	Addresses criteria and standards for planning and programming 21 of the most common non-nuclear munitions facilities on Air Force installations, both within the continental United States and at overseas locations.	CPC is addressed in Section 3.3.9 of Vol. 1. Vol. 2 contains multiple references to corrosion criteria and deterioration.
Engineering technical letters (ETLs) (dates vary) 16 letters	ETL subjects include reliability and maintainability design checklists, procedures to retard reflective cracking, preventing concrete deterioration, design criteria for prevention of mold, inspection of drainage systems, etc.	The ETL provides an expedient transmission method for new findings, technologies, and related F&I technical knowledge. It might reference criteria. It indicates who in the Air Force should read and follow the guidance provided.	The ETLs listed provide CPC-related guidance and discoveries to assist the field installations with their base maintenance responsibilities.

Policy, guidance, or regulation	Title	Relevance	Applicability
AFPAM 63-128 (5 October 2009)	*Acquisition: Guide to Acquisition and Sustainment Life Cycle Management*	Provides guidance and recommended procedures for implementing Integrated lifecycle management for Air Force personnel who develop, review, approve, or manage systems, subsystems, end-items and services (referred to as programs throughout this document) procured under DODD 5000.01 and DODI 5000.02.	Multiple references to corrosion and F&I. Corrosion control and prevention planning is covered in section 2.11.14.3.
AFPAM 91-23 (May 1990)	*Facilities Engineering Maintenance and Repair of Architectural and Structural Elements of Buildings and Structures*	This manual provides technical guidance for the maintenance and repair of buildings and structures at military installations. The standards should assist in the economical preservation of structures and insure their continuous and efficient use.	There are multiple CPC references.

Notes: ACAT = acquisition category; ACSIM = Assistant Chief of Staff for Installation Management (Department of the Army); DON = Department of the Navy; DOT = Department of Transportation; EPA = Environmental Protection Agency; FEC = Facilities Engineering Command; HVAC = heating, ventilation, and air conditioning; ILS = integrated logistics support; MCAS = Marine Corps air station; NAVFAC = Naval Facilities Engineering Command; OICC = Officer In Charge of Construction; OSD = Office of the Secretary of Defense; OSHA = Occupational Safety and Health Administration; PWD = public works department; ROICC = Resident/Regional Officer in Charge of Construction; SE = systems engineering; SME = subject matter expert; SYSCOM = System and Materiel Command; TOC = total ownership cost; UFC = unified facility criteria; UFGS = Unified Facilities Guide specifications.

Appendix C
Criteria and the *Whole Building Design Guide*

CRITERIA

Criteria are very important for successful corrosion protection and control (CPC) because they provide corrosion guidance on a variety of topics at different levels of planning, design, construction, and sustainment. In the case of unified facilities criteria (UFCs), corrosion criteria tend to be applied at the macro level. The majority of specifications and design manuals have prescriptive corrosion prevention requirements. Typically, these requirements represent an industry standard for a high level of corrosion protection. The practice evolved from years of incorporating feedback from users and subject matter experts who recognized the benefits of longer component service life and lower maintenance on total lifecycle costs, given the realities of underfunded maintenance budgets, high reliability requirements, severe environments, and aggressive usage. Criteria coverage includes protective coatings and paints, operations and maintenance of water supply systems, operation and maintenance of cathodic protection systems, architecture, structural engineering, tropical engineering, and many more.

In the case of unified facilities guide specifications (UFGSs), corrosion-criteria are applied at a more micro level. Subjects include metal roof panels, electric and electronic control systems for HVAC, cold storage refrigeration system, cathodic protection systems for steel water tanks, chain link fences and gates, manufactured metal casework, and many more. Other types of criteria, such as military specifications, describe technical requirements for purchased materials. These specifications can sometimes be even more specific than UFGSs. Subjects for these types of specifications include sacrificial zinc alloy anodes, prefabricated building components, chemical conversion coatings on aluminum and aluminum alloys and many others.

WHOLE BUILDING DESIGN GUIDE

The *Whole Building Design Guide* (WBDG) is an extensive database that provides government and industry practitioners with access to information regarding a broad range of building-related guidance, criteria, policy, and technology. This information is provided using a “whole building” perspective.

The WBDG is based on the premise that an integrated design and team approach must be applied to all phases of a project, including planning, design, construction, operations, and maintenance to successfully create a high-performance building. Most of the information found on the WBDG is organized into three categories:

design guidance, project management, and operation and maintenance. This is done in an effort to provide the field with a broad understanding while also providing more specific information that is targeted at government and industry practitioners. Federal agencies use the WBDG as a database for criteria, policy, and technical guidance regarding design of high performance and sustainable buildings.

The criteria found on the WBDG are based generally on industry standards. An industry standard is an established norm or requirement about technical systems, usually presented in the form of a formal document. It establishes uniform engineering or technical criteria, methods, processes, and practices. Industry standards can also be found in the form of reference specifications. These are standardized mandatory language documents that prescribe materials, dimensions, and workmanship that are referenced in contract documents. An industry standard may be developed independently by a corporation, regulatory body, or military organization. Industry standards can also be developed by groups, such as trade unions or trade associations. The standards referenced in criteria are usually written and maintained by standards organizations such as the American National Standards Institute (ANSI), ASTM International, the Institute of Electrical and Electronic Engineers (IEEE), or National Association of Architectural Metal Manufacturers (NAAMM).

By referencing industry standards, the whole of industry, both government and non-government, can maintain uniformity and consistency. This allows government organizations to cut down on the cost and time it takes to create new criteria. Also, uniformity allows for interoperability between government and non-government organizations performing work together. A military organization, such as Naval Facilities Command (NAVFAC) or U.S. Army Corps of Engineers (USACE), would be able to delegate work to a contractor who would be able to provide the quality that they expect. This is because the standards, specifications, requirements, etc. that both organizations are working off of are the same.

Funding support for the WBDG is provided by the Office of the Secretary of Defense (specifically, DUSD[I&E]), the Naval Facilities Engineering Command, the Army Corps of Engineers, the U.S. Air Force, the U.S. General Services Administration (GSA), the Department of Veterans Affairs, the National Aeronautics and Space Administration (NASA), the Department of Energy, and the Sustainable Buildings Industry Council (SBIC). The Engineering Innovation and Criteria Office at NAVFAC Atlantic provides a substantial role for DoD and the military services to ensure the criteria programs are managed and sustained. The WBDG is managed by the National Institute of Building Sciences (NIBS).

The WBDG's website is at www.wbdg.org. The NAVFAC Design Build Master, which contains performance technical specification, can be found at www.wbdg.org/NDBM/.

SUMMARY OF WBDG ANALYSIS

A search of the WBDG returned 3,920 search results for seven keywords: corrosion, cathodic, deterioration, structural deterioration, rust, mold and mildew. These keywords provide a broad and diverse overview of corrosion-related content. They are also representative of commonly used terms in criteria and policy and are consistent with the congressional definition of corrosion.

The keyword search results were analyzed until a sufficient number of the documents had been investigated and the most pertinent documents had been found. Of the 3,920 search results returned, 1,402 were analyzed for possible CPC relevance. Most of the returned search results contained only one or two references for one or more of the keywords. Criteria documents are holistic, which means if a design or construction action "touches" multiple material types and engineering disciplines (civil, mechanical, electrical, etc.), it is appropriate to address corrosion in that context. For the purposes of the FICE study criteria assessment, it was determined that documents that included three or more corrosion references were considered "relevant" for inclusion in the study statistics. Therefore, from these search results, 414 total criteria documents were found to be relevant to corrosion prevention and control. These criteria documents were pulled from a variety of different types of resources. These resource types are listed in Table C-1, which includes a description of the content.

Table C-1. Types of Resources Providing Documents for the WBDG Corrosion Search Results

Resource name	Description
Military specification (MIL-SPEC)	Describes technical requirements for purchased materials that are military or substantially modified commercial items. The format and content requirements are prescribed in MIL-STD-961.
Military detail (MIL-DTL)	Specifies design requirements. This includes materials that will be used, how a requirement is to be completed, or how an item should be fabricated or constructed.
Military standard (MIL-STD)	Establishes uniform engineering and technical requirements for military-unique and substantially modified commercial processes, procedures, practices, and methods. The format and content requirements are prescribed in MIL-STD-962.
Military proof (MIL-PRF)	Covers requirements in terms of the required results with criteria for verifying compliance, but without stating the methods for achieving the required results. It defines the functional requirements for the item, the environment in which it must operate, and interface and interchangeability characteristics.
Military handbook (MIL-HDBK)	Provides guidance regarding standard procedural, technical, engineering, or design information about the material, processes, practices, and methods covered by the Defense Standardization Program. The format and content requirements are prescribed in MIL-STD-962.
Unified Facilities Guide specifications (UFGSs)	Joint effort of the U.S. Army Corps of Engineers (USACE), Naval Facilities Engineering Command (NAVFAC), Air Force Civil Engineer Center (AFCEC), and NASA. UFGSs are used for specifying construction for the military services.

Table C-1. Types of Resources Providing Documents for the WBDG Corrosion Search Results

Resource name	Description
Unified facilities criteria (UFC)	Provide planning, design, construction, sustainment, restoration, and modernization criteria, and apply to Military Departments, Defense Agencies, and DoD field activities in accordance with USD(AT&L) Memorandum dated 29 May 2002. The United States Army Corps of Engineers (HQUSACE), Naval Facilities Engineering Command (NAVFAC) and the Office of the Air Force Civil Engineer are responsible for administration of the UFC system. Requirements and procedures for development and maintenance of UFC documents are prescribed in MIL-STD-3007.
Performance technical specifications (PTSs)	Provide generalized technical requirements that apply to multiple facility types and include more requirements than are applicable to any one project.
Commercial item description (CID)	CIDs are product descriptions that concisely describe the most important characteristics of a commercial product. CIDs are official U.S. government procurement documents and are uniquely numbered in a federal series, prominently dated for easy reference and appropriately titled (according to current Federal labeling policies).
Federal specification	A specification that is mandatory for use by all Federal agencies. These documents are issued and controlled by the General Services Administration (GSA).

Not all search results yielded relevant documents. In fact, a large percentage of the total search results were duplicates from other keywords or were altogether not applicable to the development of a statistical base relevant to corrosion. Also, it was found that most of the search results obtained from the keyword “mold” were in reference to the process of “molding” (the act of molding an object or materiel) which is has nothing to do with corrosion.

Examples of key corrosion documents found in the search results is presented in Table C-2, which includes the source of the WBDG criteria and a brief description of the document.

Table C-2. List of Key Criteria Documents Found in WBDG Search Results

Policy	Subject	Keywords	Description
Military specifications and standards			
MIL-PRF-81733D (15 May 1998)	*Sealing and Coating Compound, Corrosion Inhibitive*	◆ Corrosion (20 hits)	Covers accelerated, room temperature curing synthetic rubber compounds used for sealing and coating of metal components on weapons and aircraft systems for protection against corrosion.
MIL-STD-188-125-1 (7 April 2005)	*High-Altitude Electromagnetic Pulse* (HEMP) *Protection for Ground-Based* C41 *Facilities Performing Critical, Time-Urgent Missions,* Part 1 “Fixed Facilities”	◆ Corrosion (10 hits) ◆ Cathodic	Provides requirements and design objectives for high-altitude electromagnetic pulse (HEMP) mitigation of facilities that perform crucial and time sensitive command, control, and communications.
MIL-DTL-5541F (11 July 2006)	*Chemical Conversion Coatings on Aluminum and Aluminum Alloys*	◆ Corrosion (19 hits)	Covers chemical conversion coatings that are formed due to reaction of chemical conversion materials with aluminum and aluminum alloys.

Table C-2. List of Key Criteria Documents Found in WBDG Search Results

Policy	Subject	Keywords	Description
Military handbooks			
MIL-HDBK-419A (29 December 1987)	*Grounding, Bonding, and Shielding for Electronic Equipment and Facilities*	◆ Corrosion (86 hits) ◆ Cathodic (24 hits) ◆ Rust (1 hit) ◆ Mold (1 hit)	Provides information regarding grounding, bonding, and shielding practices that are recommended for electronic equipment. This handbook is comprised of two volumes. Volume 1 covers the principles of personal protection, fault protection, lightning protection, interference reduction and EMP protection for C-E facilities. Volume 2 covers the practical steps and procedures to be followed in structural and facility development, electronic engineering, and in equipment development.
MIL-HDBK-1025/4 (1 February 1999)	*Cathodic Protection Field Testing*	◆ Corrosion (41 hits) ◆ Cathodic (30 hits)	Summarizes actions to be taken in operating and maintenance of various cathodic protection systems in use at military installations.
Unified Facilities Guide specifications			
UFGS-02 85 00.00 20 (May 2011)	*Mold Remediation*	◆ Mold (84 hits)	Covers requirements for demolition, cleaning, removal, and disposal of materials contaminated with mold.
UFGS-03 31 29 (August 2012)	*Marine Concrete*	◆ Corrosion (57 hits) ◆ Cathodic (3 hits) ◆ Rust (3 hits)	Covers requirements for reinforced concrete that is exposed to marine and chloride environments.
UFGS-09 90 00 (May 2011)	*Paints And Coatings*	◆ Corrosion (3 hits) ◆ Rust (19 hits) ◆ Deterioration (9 hits) ◆ Mold (6 hits) ◆ Mildew	Covers requirements for painting of new and existing, interior and exterior substrates.
UFGS-12 31 00 (May 2009)	*Manufactured Metal Casework*	◆ Corrosion (15 hits)	Covers requirements for fabrication, finish, installation, cleaning, and inspection of metal casework.
UFGS-13 34 19 (November 2011)	*Metal Building Systems*	◆ Corrosion (7 hits) ◆ Rust (2 hits)	Covers requirements for pre-engineered fabricated metal structures.
UFGS-23 00 00 (August 2010)	*Air Supply, Distribution, Ventilation, and Exhaust Systems*	◆ Corrosion (33 hits) ◆ Rust (3 hits) ◆ Deterioration (3 hits)	Covers requirements for air supply, distribution, ventilation, and exhaust portions of HVAC systems.
UFGS-26 42 13.00 30 (April 2006)	*Cathodic Protection by Galvanic Anodes*	◆ Corrosion (26 hits) ◆ Cathodic (42 hits)	Covers requirements for cathodic protection systems that use galvanic anodes for underground piping and buried or submerged structure.
UFGS-26 42 14.00 10 (August 2008)	*Cathodic Protection System (Sacrificial Anode)*	◆ Corrosion ◆ Cathodic	Covers requirements for cathodic protection systems that use continuous flow direction current from sacrificial anodes.

Table C-2. List of Key Criteria Documents Found in WBDG Search Results

Policy	Subject	Keywords	Description
UFGS-26 42 19.10 (November	*Cathodic Protection Systems (Impressed Current) for Lock Miter Gates*	◆ Corrosion (43 hits) ◆ Cathodic (65 hits)	Provides requirements for lock miter gate cathodic protection systems.
UFGS-33 11 00 (February 2010)	*Water Distribution*	◆ Corrosion (35 hits) ◆ Cathodic (5 hits)	Covers requirements for potable and nonpotable (raw water and sea or salt water) systems, were the largest size pipe has a diameter of 600 mm 24 inches and the maximum working pressure that does not exceed 1400 kPa 200 psi for pipelines 300 mm 12 inch size and smaller and 1000 kPa 150 psi for pipelines larger than 300 mm 12 inch size.
UFGS-40 05 13 (October 2007)	*Pipelines, Liquid Process Piping*	◆ Corrosion (40 hits) ◆ Cathodic (30 hits) ◆ Rust	Covers requirements for above- and below-grade liquid process piping located both inside and outside of treatment plants.
Unified facilities criteria			
UFC 3-190-06 (16 January 2004)	*Protective Coatings and Paints*	◆ Corrosion (82 hits) ◆ Cathodic (35 hits) ◆ Rust (54 hits) ◆ Deterioration (45 hits) ◆ Mold ◆ Mildew (60 hits)	Encloses Military Handbook 1110 (17 January 1995) and re-issues it as a UFC. Provides guidance for DoD personnel who wish to apply architectural paints or protective coatings to military structures fixed in place.
UFC 3-230-02 (10 July 2001)	*Operations and Maintenance of Water Supply Systems*	◆ Corrosion (116 hits) ◆ Cathodic (22 hits) ◆ Rust (16 hits)	Provides technical guidance for operating and maintaining water supplies, treatment plants, storage facilities, and distribution systems at military installations. Applies to all personnel who are responsible for operation and maintenance of fixed-base water systems.
UFC 3-240-13FN (25 May 2005)	*Operations and Maintenance: Industrial Water Treatment*	◆ Corrosion (471 hits) ◆ Cathodic (18 hits) ◆ Rust (22 hits) ◆ Mildew	Provides an overview of industrial water treatment operations and management.
UFC 3-440-05N (28 November 2006)	*Tropical Engineering*	◆ Cathodic (79 hits) ◆ Cathodic (10 hits) ◆ Rust (11 hits) ◆ Mold (5 hits) ◆ Mildew (14 hits)	Contains a full text copy of MIL-HDBK-1011/1. Provides a general overview of information related to construction within tropical regions.
UFC 3-570-02A (01 March 2005)	*Cathodic Protection*	◆ Corrosion (49 hits) ◆ Cathodic (134 hits)	Contains TM 5-811-7. Provides general design guidance for cathodic protection systems.
UFC 3-570-02N (16 January 2004)	*Electrical Engineering Cathodic Protection*	◆ Corrosion (224 hits) ◆ Cathodic (467 hits)	Contains MIL-HDBK-1004/10. Intended to be used in the design and construction of cathodic protection systems for the purpose of mitigation of corrosion of buried or submerged metallic structures.

Table C-2. List of Key Criteria Documents Found in WBDG Search Results

Policy	Subject	Keywords	Description
UFC 3-570-06 (31 January 2003)	*Operations and Maintenance: Cathodic Protection Systems*	◆ Corrosion (516 hits) ◆ Cathodic (382 hits) ◆ Rust (4 hits)	Provides guidance for inspection and maintenance of cathodic protection systems.
UFC 4-150-07 (19 June 2001)	*Operation and Maintenance: Maintenance of Waterfront Facilities*	◆ Corrosion (129 hits) ◆ Cathodic (46 hits) ◆ Rust (26 hits)	Provides guidance for the inspection, maintenance, and repair of waterfront structures and related facilities. Is also used as a reference for planning, estimating, and performing technical maintenance and repair work.
Performance technical specifications			
NAVFAC B30 (November 2010)	*Roofing*	◆ Corrosion (12 hits) ◆ Rust ◆ Deterioration (3 hits)	
NAVFAC G30	*Site Civil/Mechanical Utilities*	◆ Corrosion (13 hits) ◆ Cathodic (10 hits)	

Although criteria are unified across the three military services, not all criteria are applicable to all DoD components and participating organizations. UFC and UFGSs that apply only to certain organizations are denoted in the document number. UFCs that are unified for use by all participating agencies do not have a letter at the end of the document number. UFCs that are service-specific have a letter, or letters, at the end of the document number ("A" indicates Army, "N" indicates Navy, and "F" indicates Air Force). A UFC denoted by multiple letters indicates it is used by more than one service.

Example: UFC 3-430-08N, *Central Heating Plants* (The "N" identifies this UFC as Navy-specific).

UFGSs that are unified for use by all participating agencies have a level 3 or level 4 master format number. UFGSs that are service-specific have a fifth level number. The number "10" indicates the USACE, a "20" indicates NAVFAC, a "30" indicates Air Force Civil Engineer Center (AFCEC), and a "40" indicates NASA.

Examples:

- UFGS-23 63 00.00 10, *Cold Storage Refrigeration System* (The "10" denotes that this UFGS is USACE specific)
- UFGS-40 18 00.00 40, *Vacuum Systems Process Piping* (The "40" denotes that this UFGS is NASA specific).

Examples of service-/agency-specific criteria are listed in Table C-3.

Table C-3. Examples of Service-/Agency-Specific Criteria

Policy	Subject	Keywords	Description
Unified Facilities Guide specifications			
UFGS-23 35 19.00 20 (February 2010)	*Industrial Ventilation and Exhaust*	◆ Corrosion (22 hits)	Provides requirements for blower and exhaust systems for the removal of flammable vapors. This includes paint spraying residue, corrosive fumes, dust, and stock conveying.
UFGS-23 63 00.00 10 (October 2007)	*Cold Storage Refrigeration System*	◆ Corrosion (12 hits) ◆ Rust (1 hit)	Covers requirements for refrigeration equipment for cold storage facilities. This document coves coil corrosion protection extensively.
UFGS-26 42 15.00 10 (November 2008)	*Cathodic Protection System (Steel Water Tanks)*	◆ Corrosion ◆ Cathodic	Covers requirements for cathodic protections systems using impressed current anodes.
UFGS-26 42 17.00 10 (November 2008)	*Cathodic Protection System (Impressed Current)*	◆ Corrosion ◆ Cathodic	Covers requirements for cathodic protection systems that use impressed current anodes.
UFGS-33 60 00.00 10 (April 2008)	*Central High Temperature Water Generating Plant and Auxiliaries*	◆ Corrosion (14 hits) ◆ Rust (5 hits)	Covers requirements for high temperature water plants with capacities that are over 2,930 kW (10,000,000 Btuh), and produce water at temperatures of 115–227°C (240–440°F) at pressures up to 2.8 MPa (400 psig). Covers many different CPC topics such as rust prevention, rust-inhibiting coatings, and cold-end corrosion.
UFGS-40 18 00.00 40 (February 2011)	*Vacuum Systems Process Piping*	◆ Corrosion (14 hits)	Covers requirements for aboveground low-vacuum systems. Contains many references to corrosion-resistant steel requirements.
Unified facilities criteria			
UFC 3-430-01FA (25 July 2003)	*Heating and Cooling Distribution Systems*	◆ Corrosion (11 hits) ◆ Cathodic (20 hits)	Contains TI 810-32. Provides guidance and criteria for the design and construction of heating and cooling distribution systems and supplements information in the "Notes to the Designer" of the guide specifications. Covers multiple CPC topics such as corrosion-resistant materials, internal corrosion, cathodic protection, and others.
UFC 3-430-08N (16 January 2004)	*Central Heating Plants*	◆ Corrosion (57 hits) ◆ Cathodic (4 hits) ◆ Deterioration (4 hits)	Contains MIL-HDBK-1003/6. Provides criteria for designing steam and high temperature water central and individual heating plants. Covers many different CPC topics including economizer corrosion controls. Section 8.6.5 covers general corrosion requirements. Section 10.6 covers general corrosion prevention requirements.

Table C-3. Examples of Service-/Agency-Specific Criteria

Policy	Subject	Keywords	Description
UFC 4-171-01N (16 January 2004)	*Design: Aviation Training Facilities*	◆ Corrosion (12 hits) ◆ Rust (5 hits) ◆ Mold (2 hits) ◆ Mildew (6 hits)	Contains MIL-HDBK-1027/4A. Intended to assist in design of high quality aviation training facilities at reasonable cost in compliance with DoD criteria. Covers design requirements for aircraft operation and maintenance training facilities. Covers many CPC-related topics such as corrosion-resistant materials, corrosion resistant finishes, and others.
UFC 4-211-02NF (10 January 2005)	*Corrosion Control and Paint Finishing Hangars*	◆ Corrosion (56 hits)	Provides specific design criteria of Navy and Marine Corps aircraft corrosion control and paint hangars.

Appendix D
Corrosion Control Technology

Facilities and infrastructure (F&I) technology projects play an important role when finding solutions for corrosion prevention and control (CPC). The benefits gained from these technologies affect both DoD and industry.

With a keen awareness of the unmitigated ravages of corrosion on the lifecycle of F&I, the inclusion of new technologies in critical stages of the F&I lifecycle both extend life expectancy and reduce SRM costs. As technologies evolve, keeping the knowledge base current is essential to achieving reduced lifecycle costs.

Technologies are those innovative or non-standard technical processes and products that may later be identified in criteria. Technology includes the practical application of better products, processes or procedures, and standards. Discoveries of new CPC technologies occur when the combined efforts of industry, academia, and DoD result in corrosion-cost savings. The incorporation of these successful CPC-related outcomes as criteria updates ensures CPC factors are considered in the construction of new facilities and infrastructure as well as in day-to-day sustainment operations.

Research, development, testing, and evaluation (RDT&E) is an appropriation used by DoD to fund research efforts performed by both contractors and government organizations in the development of equipment, material, or computer application software. This includes services, equipment, components, materials, end items and weapons used in such efforts.[1] Another source of new technology development is corrosion-related service-level RDT&E projects. In some cases the Director of the Corrosion Protection Office (D, CPO) offers technology funding that may be used to demonstrate or expand the knowledge of corrosion-related elements of these military service RDT&E projects.

Table D-1 lists D, CPO efforts to further understand and improve technology advancements for DoD. Project summaries and outcomes of corrosion-related RDT&E can be found in Table D-2. Examples of non-DoD, private sector, and other non-government industry corrosion-related technology and improvements projects can be found in Table D-3.

[1] https://dap.dau.mil/acquipedia/Pages/ArticleDetails.aspx?aid=e933639e-b773-4039-9a17-2eb20f44cf79

Table D-1. List of Corrosion-Related D, CPO–Funded Projects

Air Force projects
2005
AF-F-116: **SCADA Monitoring of Cathodic Protection Systems, Robins Air Force Base** (2005) The objective of this project is to remotely monitor cathodic protection system operations (using supervisory control and data acquisition, or SCADA) in an effort to ensure they meet Air Force regulations, NACE standards, and the Code of Federal Regulations. Monitoring efforts use hardwire and radio unit instrumentation to transmit real-time voltage and current readings back to central monitoring.
2011
F11AF09: **Flexible Steel Reinforced Polyethylene Fuel Piping** (2011) The objective of this project is to explore the use of steel reinforced polyethylene piping to reduce corrosion costs, installation time, and construction costs. The technology utilized in this project is steel reinforced polyethylene piping. This piping offers benefits of non-metallic piping for corrosion protection with ANSI pressure ratings comparable to rigid steel pipe. This project will replace a portion of the underground piping in a POL Bulk Storage area. Use of Flexible Steel Polyethylene Piping is applicable in all military services for fuel transfers.
2012
F12AF01: **Fluoropolymer Coated Fasteners** (2012) The objective of this project is to demonstrate the elimination of corrosion on fasteners (bolts) by using fluoropolymers coatings. Fluoropolymer lubricants in conjunction with high performance resins create Fluoropolymer coatings that provide excellent corrosion and chemical resistance. This project's approach is to replace a conventional bolts with fluoropolymer coated bolts in three projects, each involving underground water pipe with mechanical (bolted) joints, above ground fuel piping flanges and a structural application such as stairs, beams or girders. This would provide a good comparison in a variety of applications and environments.
Navy projects
2005
N-F-221: **Self-Priming Cladding for Splash Zone Steel** (2005) The objective of this project was to increase the service life of splash zone steel coatings. The "splash zone" is defined as the area between the year's lowest tidal mark and up to 10 feet above the year's highest tidal mark. It is extremely difficult to protect steel structures against corrosion in this zone, where corrosion rates on unprotected steel have been documented to exceed 30 mils per year. This project applied a new technology developed by the New Small Business Innovation Research (SBIR) that employs 40+ mils epoxy novolac/polysulfide. The NAVFAC EXWC is transitioning using criteria updates, which are currently in development. Specifically, UFGS-09 97 13.26, Coating of Steel Waterfront Structures; UFGS-09 97 13.15, Epoxy/Fluoropoly-urethane Interior Coating of Welded Steel Petroleum Fuel Tanks; and UFGS-09 97 13.17, Three Coat Epoxy Interior Coating of Welded Steel Petroleum Fuel Tanks. UFGS-09 97 13.15 and 17 may be merged into a UFGS for all services.
N-F-222: **Red Hill Pipeline Corrosion Assessment, Fleet Industrial Supply Center** (FISC) **Pearl Harbor** (2005) The objective of this project is to conduct an in-line inspection of a 32-inch diesel pipeline from the Red Hill Storage Facility to Pearl Harbor to determine its extent of corrosion and integrity. This will be accomplished using "smart pigs," inspection vehicles that move inside a pipe by the flowing material.
N-F-223: **Ambient Temperature Cured Coatings** (2005) The objective of this project is to define the functional parameters for application and use of ambient temperature cured coatings. These coatings will improve long-term performance, reduce maintenance costs, and compile and assess ongoing installation at Jacksonville Naval Air Station (NAS). The primary interest for application of this technology is on steel structures in aggressively corrosive environments, but it will also be applied to other areas, such as substrates and environments to maintain or restore existing coating systems.

Table D-1. List of Corrosion-Related D, CPO–Funded Projects

2005 cont'd
N-F-229: **Integrated Concrete Pier Piling Repair and Corrosion Protection System** (2005) Reinforced concrete pilings at Ford Island in Pearl Harbor have suffered from significant corrosion of the steel rebar. This resulted in the loss of load handling capacity because of concrete spalling. The Ford Island bridge repair project was to install a commercially available, integrated concrete pier piling repair and corrosion protection system on spalled or cracked concrete pier piling. The technology utilized in this project consists of integrated concrete repair and cathodic protection prefabricated in a fiberglass jacket, referred to as LifeJacket®. This technology restores structures to optimum operational condition; reduces recurrence of reinforcing steel corrosion; reduces maintenance and life-cycle costs; and increases service life. The repair project served as a test program for the LifeJacket® technology. This integrated pile repair corrosion protection system comprises a high purity expanded zinc mesh cathodic protection anode mounted into a durable, stay-in-place fiberglass form. This positions the anode material the appropriate distance relative to the steel rebar in the piling. The form creates an essential annular space for filling with concrete material to complete or improve the structural repairs to the piling. A supplemental bulk anode is added to protect the submerged portion of the pile and minimize current demand on the lower portion of the anode mesh. The system comes ready to install with all components pre-positioned and fixed in place. The external jacket material is a durable fiberglass shell, equipped with a unique interlocking seam for easy installation. Based on the test results, the LifeJacket® technology generally functions as advertised; the pile reinforcing steel is adequately protected from corrosion and no further corrosion-caused spalling and delaminations in the portions of piles with installed LifeJackets® is anticipated for at least 20 years. The system provides a viable repair alternative to reinforced concrete piles contaminated with chlorides, that require significant crack and spall repairs, and where full pile replacement is not economical. From July through December 2007, NAVFAC EXWC conducted a series of tests after system commissioning to determine the operating status and effectiveness of LifeJacket® galvanic protection technology. These tests and the analysis were funded by D, CPO Project N-F-229, and results have been included in a pending draft rewrite of UFC 3-570-02, Cathodic Protection Design.
2006
FNV01: **Corrosion Project Utilizing IR Drop Free Sensors** (2006) The objective of this project was to develop IR drop-free sensors and a corresponding inspection tool to control and maintain cathodic protection systems on cross-country pipelines. The sensors are used to determine the rate of corrosion on the pipeline system in order to validate the cathodic protection system. IR drop free sensors measure the potential of underground pipelines immediately after briefly interrupting the cathodic protection current. This project was applied to the Guam cross-country pipeline that runs from the Tiyan Pump House to the Anderson Air Force Base Tank Farm. Results from this project have been included in a pending draft rewrite of UFC 3-570-02, Cathodic Protection Design.
FNV04: **Modeling Advance Waterfront Metallic Material Corrosion and Protection** (2006) The objective of this project is to accurately represent corrosion behavior of structures using corrosion mitigation modeling software. Specific tasks to achieve this goal include acquiring accurate polarization data, modeling structure surfaces, validating models, and developing requirements and recommendations. This project will utilize three-dimensional boundary element modeling (BEM) software which can accurately predict corrosion behavior using non-linear material polarization relationships. BEM enables analysis of specific facility corrosion issues and corrosion mitigation alternatives. Current plans call for utilization of BEM analysis on a Navy modular hybrid pier and underwater unexploded ordinance.
FNV06: **Wire Rope Corrosion for Guyed Antenna Towers** (2006) The objective of this project is to develop reliable inspection tools for the purposes of detecting internal corrosion of structural guy wires, measure corrosive state of guy wires and develop realistic guy replacement criteria. These tools will be built in the form of a "vehicle" comprised an electromagnetic flux leakage sensor and other inspection methods. This "vehicle" will be able to travel along the guy wire and reliably measure and monitor guy wire corrosion over time and space. The inspection tool will ride remotely along each guy wire in order to measure the corrosive state along the full length of the wire. The inspection tool and guy wire corrosion managing process will be applicable for all Navy very low frequency and low frequency (VLF/LF) antennas. The project will initially implement the inspection tool and develop a replacement timetable at the Holt antenna in Australia, which has 357 guy wires.

Table D-1. List of Corrosion-Related D, CPO–Funded Projects

2006 cont'd
FNV07: **Solar Powered Cathodic Protection System** (2006) The objective of this project was to design and install a solar powered cathodic protection system that will fully and adequately protect water and fuel distribution pipelines from corrosion. This project entailed combining a straightforward impressed current cathodic protection system with a solar-power supply and control system for the rectifier in place of the traditional AC power that is currently not readily available. This project was applied to underwater water utility and fuel pipelines in the eastern side of Guantanamo Bay, Cuba. Results from this project have been included in a pending draft rewrite of UFC 3-570-02 Cathodic Protection Design.
FNV13: **Ambient Temperature Cured Coatings** (2006) The objective of this project is to determine the functional parameters under which ambient temperature cured (ATC) coatings can be used. This project will utilized ATC fluoropolymers, a generic class of coatings that start with a polyurethane resin "back-bone," which is then fluorinated under high pressure and heat to create the modified coating resin. The resulting coating surface is easy to clean–resistant to chemicals, UV, ablation, abrasion, and impact–and will mitigate the growth of mold/mildew. This technology applies to all Navy and Marine Corps facilities especially exterior steel and interior fuel tanks.
2007
F07NV03: **Concrete Corrosion Inhibitors** (2007) The objective of this project is to determine the fundamental influence of commercial inhibitors on corrosion behavior of steel reinforcement in environments typical of the chemistry of marine concrete in different stages of deterioration. The electrochemical (anodic and cathodic) current flow of corrosion cells that develop or are inhibited in concrete environments will be measured. This will provide a direct measure of the effectiveness of inhibitors under evaluation for concrete repair. The results will directly impact practices in use for concrete repairs, overlays, and rehabilitation projects. The information developed and data obtained through this project will be used to support the delivery of innovative solutions to mitigate corrosion of the waterfront infrastructure through the waterfront subject matter expert (SME) programs.
F07NV04: **Navy Remote Monitoring Unit** (2007) The objective of this project was to install and demonstrate the effectiveness of recently developed cathodic protection systems rectifier remote monitoring units (RMU) utilizing satellite data transmission. This project installed and demonstrated the effectiveness of recently developed CPS RMUs utilizing satellite data transmission for the fuel storage and distribution CPS located in Guam to verify the ability to receive the information from this remote region. Successful implementation of this technology in Guam will demonstrate its transition for use on other Navy and DoD installations, as well as other critical facilities that utilize cathodic protection systems. These facilities include waterfront structures, potable water tanks, and utility piping. Results from this project have been included in a pending draft rewrite of UFC 3-570-02 Cathodic Protection Design.
F07NV07: **Stainless Steel Reinforcing for Concrete Structures** (2007) The objective of this project is to determine constructability and long term performance by using candidate stainless steel reinforcing materials in a working marine concrete structure repair project and installing them in new construction. The project will be accomplished in two phases—development and implementation. The development phase will consist of comparing the lower cost corrosion resistant materials with austenitic stainless steel 316 and the commonly used duplex grade 2205. The installation phase will consist of installing top performing alloys into a waterfront facility repair project or new construction. This project will be implemented as part of a major pier repair project in Pearl Harbor, Hawaii.
2008
F08NV17: **Concrete Galvanode Zinc Rod Cathodic Protection Systems for Concrete Rebar, Kilo (Hawaii) Wharf** (2008) The objective of this project is to demonstrate the effectiveness of a discrete galvanic anode cathodic protection system for the purpose of mitigating corrosion during the repair of reinforced concrete. This project will demonstrate the effectiveness of alkali-activated bulk zinc anodes by installing them in the Kilo Wharf upgrade project located in Guam. These anodes will be used to mitigate future corrosion damage to the existing caisson wharf components.
F08NV18: **Encapsulated Embedded Galvanic Cathodic Protection for Concrete Dry-Dock Patches** (2008) The objective of this project is to demonstrate the design and installation methodology of embedded galvanic cathodic protection for use in Navy dry-docks. This project will utilize zinc anodes that are encased in a proprietary porous solid matrix which is formulated to absorb the corrosion by-products thus eliminating any internal stresses to the concrete that may otherwise lead to internal cracking. These anodes will be embedded into the concrete.

Table D-1. List of Corrosion-Related D, CPO–Funded Projects

2009
F09NV04**: ER Probe Corrosion Sensors** (2009) The objective of this project was to demonstrate and evaluate the use of recently developed electrical resistance probes to improve the corrosion monitoring systems on Navy piers. Electrical resistance probes have been developed that will allow direct measurement of the corrosion rate of a structure. They can be used to indicate the effectiveness of cathodic protection in obscure areas. This technology was demonstrated and evaluated on the Delta-Echo POL pier on Naval Base Guam. Results from this project have been included in a pending draft rewrite of UFC 3-570-02 Cathodic Protection Design.
F09NV05: **Tank Interior Corrosion Sensors** (2009) The objective of this project is to demonstrate the use of electrical resistance probes that have the capability to continuously monitor corrosion conditions in corrosion “hotspots” on the interior bottom of POL storage tanks. The technology utilized in this project consists of an electrical resistance (ER) monitoring system that operates by measuring the change in electrical resistance of a metallic element immersed in a product media relative to a reference element sealed within the probe body. The ER probe system will be designed by NAVFAC Engineering and Expeditionary Warfare Center engineers and installed in fuel storage tanks at NAS Patuxent River and Marine Corps Base Camp Lejeune.
F09NV07: **High Volume Fly Ash Concrete** (2009) The objective of this project is to provide a no-cost alternative to the mitigation of steel reinforcement corrosion in concrete used for military construction. This project will demonstrate the use of fly ash at 40percent replacement of the Portland cement in waterfront concrete structures to improve corrosion resistance of the reinforcing steel. Installation and demonstration of this technology will be part of a construction project in Bremerton, WA. Results will be documented and will help determine a new waterfront structure design standard.
F09NV09: **Wire Rope for Antenna Tower Guy Wires** (2009) The objective of this project is to develop tools for inspecting guy wire ropes and develop a realistic timetable for the systematic replacement of guy wires. These tools will be used to perform baseline inspections of guy wires in order to identify breaks, corrosion, and other damage. These tools will be built in the form of a “vehicle” comprised an electromagnetic flux leakage sensor and other inspection methods. This “vehicle” will be able to travel along the guy wire and reliably measure and monitor guy wire corrosion over time and space. The inspection tool will ride remotely along each guy wire in order to measure the corrosive state along the full length of the wire. The inspection tool and guy wire corrosion managing process will be applicable for all Navy very low frequency and low frequency (VLF/LF) antennas. The project will initially implement the inspection tool and develop a replacement timetable at the Holt antenna in Australia, which has 357 guy wires.
2010
F10NV02: **Electrochemical Chloride Extraction of Reinforced Concrete** (2010) This objective of this project is to demonstrate the electrochemical chloride removal as a means of mitigating corrosion on reinforced concrete in waterfront structures. Electrochemical Chloride Extraction (ECE) is essentially a simple process whereby chloride ions are removed from chloride contaminated concrete through ion migration enabled by the application of cathodic protection current at high current densities for a short duration. The ECE process uses a temporary anode (typically a coated titanium mesh) and relatively high current density applied to the steel reinforcing for approximately four to six weeks. The primary deliverable for this project will be a structurally sound, fully operational pier supported by concrete pilings containing repairs that will result in an extended pier service life with minimum required repairs and maintenance. Where appropriate, Navy Design Policies on pier repairs, Unified Facilities Criteria Documents and Guide Specifications, and Lessons Learned Reports will be developed and posted on the NAVFAC and NFEXWC waterfront design and corrosion control websites and the DoD Corrosion Exchange website.
F10NV03: **Inorganic Zinc Rich Primer/Inorganic Color Topcoat for Exterior Steel** (2010) The objective of this project will demonstrate and validate an inorganic based coating system and compare to know performance characteristics of the current organic coating system. It will also demonstrate and validate the effectiveness of an inorganic topcoat coupled with an inorganic zinc rich coating and provide a framework for the development of education and training programs for corrosion prevention and control students. This project encompasses three major elements of both 10 U.S.C. Sec. 2228 and the DoD Corrosion Prevention and Mitigation Strategic Plan: demonstrating new technology for supporting the war fighter; extending DoD collaboration with industry to model, establish and utilize best practices and processes; and integration of academia to support the education and training of the next generation corrosion workforce

Table D-1. List of Corrosion-Related D, CPO–Funded Projects

2010 cont'd
F10NV04: **Accelerated Weathering of Organic Materials** (NIST SPHERE) (2010) The NIST Integrating SPHERE is an accelerated weathering system that provides more uniform and accurate UV exposure. This project compares the weathering performance of five chemically different coating systems. The primary purpose of this project is to demonstrate and validate the use of the NIST SPHERE as a more effective tool for determining long-term coating behavior. The primary deliverable will be validation and support of the NIST SPHERE for accelerated weathering. Detailed specifications and operational instructions will also be delivered in the form of manuals (hard copy and electronic). These documents will form the foundation for developing non-government testing standards/protocols.
F10NV06: **Nickel Titanium/Titanium Carbide Coating for Cavitation of Pump Impeller Blades** (2010) This project merges the proven corrosion and erosion resistance of Ni-Ti alloy with a new ESD coating technology to deposit a composite NiTi/TiC layer that will absorb the high-pressure shocks due to cavitation and resist the erosion effects of harsh abrasive environments. ESD parameters to deposit quality NiTi coating will be developed. Where appropriate, Navy De-sign Policies for pump impeller modifications, Unified Facilities Criteria Documents and Guide Specifications, and Lessons Learned Reports will be developed and posted on the NAVFAC and NFEXWC waterfront design and corrosion control websites and the DOD Corrosion Exchange website. A final report describing the details and results of the project will be submitted to OSD and distributed to Navy as well as tri-service design agencies.
F10NV07: **Wire Rope Corrosion Reduction for Guyed Antenna Towers** (2010) The objective of this project is to develop a better understanding of all the factors involved in guy wire corrosion. Through investigation of corrosion behavior and the modes of failure, informed choices of viable options for specification of superior cable can be made. Implementation is part of this project and will serve to gauge the effectiveness of the wire rope coatings to reduce corrosion. Results will be included in a new guy wire specification that will increase the serviceable life of the new guy wires. The VLF/LF user community and NNSOC recognize the SPAWAR/NFESC partnership as the best way to investigate and implement facilities improvements relative to the VLF/LF antenna system. A final report describing the details and results of the project will be submitted to OSD and distributed to both the Navy and the SDC 32 members. It is intended that the results of this project will be available for future use by all DOD and industry wide projects.
F10NV10: **Enhanced Guidelines for Marine Concrete Repairs** (2010) This objective leverages MILCON funding with OSD funds to monitor and document the use of enhanced guidelines for concrete repairs. This guideline specification will provide guidance selection and application of materials and methods for the repair of concrete marine structures. Results will be used to plan future MILCON and establish NAVFAC policy. Where appropriate, NAVFAC Wide Design Policies (WDP) for waterfront repairs and Unified Facilities Criteria Documents and Guide Specifications (UFCDGS) will be developed for use by all of NAVFAC as well as tri-service waterfront structure installation management personnel. A final report describing the details and results of the project will be submitted to OSD and distributed to the Navy as well as other tri-service design agencies. The final report will document the use of enhanced guidelines for marine concrete repairs.
2011
F11NV02: **Pipe Wrap** (2011) The objective of this project is to evaluate a candidate pipe wrap with the required structural integrity to assess the parameters and techniques necessary for a successful repair. The pipe wrap to be tested is a carbon fiber fabric wrap with a 100 percent solids epoxy that cures into a composite material that is claimed to have excellent mechanical properties. This project will be implemented to reinforce compromised pipeline segments that cannot use cathodic protection and coating alone is not sufficient.
F11NV04: **Thermally "Insulating" Coatings** (2011) The objective of this project is to demonstrate/validate the effectiveness of thermally "insulating" coatings against conventional insulation on heated distribution lines. Some recent coatings developments include what have been billed as "insulating" coatings. Their advantage is that they are thin single coats so damage/corrosion problems to the line would not be hidden, they are easily repaired, and they do not absorb moisture so would not lose their insulating characteristics as easily as the heavier standard insulation. A smaller diameter profile may also have the added benefit of being able to fit into tighter spaces or use a larger line to provide improved service to the customer.

Table D-1. List of Corrosion-Related D, CPO–Funded Projects

2011 cont'd
F11NV05: **Pre- and Post-Stressing Concrete** (2011) The objective of this project was to explore the feasibility of pre- and post-stressing all components in typical waterfront structures, and in particular pile-support piers. Concrete is strong in compression, but has limited tensile strength. Proper application of a compressive preload in a concrete member can be used to limit the tensile stresses and the cracks that occur at critical sections. Successful application of pre- or post-stressing will minimize or eliminate macro-cracks that form under service load conditions in corrosive environments. The main deliverable for this project will be a pier with enhanced durability against corrosion. Criteria will be developed to minimize or prevent macro-cracks, and generic drawings for a typical pile-supported pier will be developed. These Criteria and the generic drawings will be incorporated into UFC 4-152-01 Design: Piers and Wharfs where appropriate. NAVFAC EXWC developed a methodology to predict the long-term service life of marine concrete using state-of-the-art software. This methodology is now integrated into UFGS 03 31 29 Marine Concrete (August 2012). In addition, the methodology is now being used in the industry.
F11NV06: **Portable Spray Gun for Coating Spot Repairs** (2011) Spot repair/coating is a regular maintenance procedure that is routinely done over a complete recoating job. Although spot treatment is less costly than a complete recoat, the frequency in which this procedure is done still makes this an expensive event. A portable spray gun for architectural finishes (waterborne coatings) was recently developed and made available for general purchase. There is no equivalent for applying industrial type coatings requiring higher pressures and meeting explosion "proof" requirements when flammable solvents are utilized. A field demonstration of this spray gun technology will be conducted at Andersen Air Force Base, Guam.
F11NV07: **Corrosion Protection for Bulk Fuel Storage Tank Bottoms** (2011) A new method must be developed to retrofit corrosion prevention and control systems for above ground storage tanks (ASTs) with a Release Prevention Barrier (RPB). This project will demonstrate the feasibility of two alternative methods: (1) installation of commercially available rod type anodes through the tank ringwall, and (2) installation of a system that will allow injection of corrosion inhibitors into the interstitial space under the tank bottom. The primary deliverable will be alternative retrofit corrosion protection systems for controlling corrosion and maintaining the fuel tanks so that costly repairs or leaks are avoided. This demonstration will provide technological and economical creditability to leverage against more costly options for cathodic protection replacements and maintain lifecycle of fuel storage tanks.
F11NV08: **Composite Pump Impellers** (2011) The objective of this project is to test and validate new fiber reinforced polymer (FRP) composite pump impellers to resist corrosion erosion and cavitation in marine environments. This project will evaluate the corrosion, erosion and cavitation advantages of FRP composite impellers over metallic impellers used in hydro pumps in Guam. Several FRP composite systems will be evaluated including: fiberglass and carbon fiber based composites and thermoset resin systems versus thermoplastic systems. The technology can be employed to immediately extend the service life of Naval facility pumps.
2012
F12NV01: **Crack Resistant Concrete Repairs** (2012) The objective of this project is to evaluate the performance of crack resistant concrete repair material developed through Small Business Innovative Research (SBIR) as compared to conventional concrete repairs. Application of this project will be conducted on Pier 14 at Naval Station Norfolk, Virginia.
F12NV02: **Cathodic Protection Anode Beds** (2012) The objective of this project is to evaluate the viability of recently developed environmentally friendly cathodic protection anode system. The technology that will be utilized in this project is EnvirAnode®, an environmentally friendly anode design. A test bed of EnviroAnodes will be installed to verify the hygroscopic properties of the material. Retrofit installation of environmentally friendly anodes for an existing cathodic protection system will occur at one or two candidate locations. The test site will be a shallow anode bed in Guam or Hawaii.
F12NV05: **Allowable Concrete Crack Widths for Reinforcement Materials** (2012) The objective of this project is to determine the allowable concrete crack widths for mitigation of corrosion of reinforcement materials. Corrosion of reinforcing steel is summarily cited as the primary cause of deterioration of concrete waterfront structures. Presently there is renewed debate as to the importance of placing limits on concrete crack size to ensure an acceptable risk against corrosion of the reinforcement. If it can be shown that corrosion of the advanced materials is insignificant for large enough crack sizes, the criteria for long term durability of concrete can be relaxed with significant cost savings.

Table D-1. List of Corrosion-Related D, CPO–Funded Projects

Army projects
2005
AR-F-311: **Measuring the Rate and Impact of Corrosion Damage on DoD Equipment and Installations** The objective of this project is to develop site-specific corrosion data and model the local effect of corrosion on various materials. The project will integrate corrosion rate measurements at various sites based on the innovative Battelle corrosion exposure rack system. This technology will be applied at more than 75 DoD, NASA, and Coast Guard test sites.
AR-F-313: **Leak Detection for Pipes at Fort Hood** The objective of this project was to implement leak detection technology on the potable water distribution system. This project used a remotely monitored acoustic sensor that can detect and record characteristic leak signature in water distribution piping. The DoD-developed signal processing discriminates leak signals from background noise and determines the approximate location of leaks. Leak information is used to target and repair areas of worst corrosion first. Application of this technology took place at the residential section at Fort Hood, Texas. Results from this project have been included in a pending draft rewrite of UFGS-33 11 00 Water Distribution.
AR-F-314: **Non-Hazardous Corrosion Inhibitors/SMART Control Systems for Heating and Cooling** The objective of this technology was to implement an improved approach for controlling corrosion, scale, and microbiological growth in boilers and cooling towers. This was accomplished using innovative non-hazardous green chemical treatments and a smart monitoring and control system. The smart monitoring and control system has the capability to self-adjust corrosion inhibitor application based on real time corrosion rates. Control systems were installed at seven cooling towers at Ft. Rucker, eleven cooling towers at Ft. Hood, three cooling towers at Redstone Arsenal, one cooling tower and one boiler system at Brooke Army Medical Center, and two towers and one boiler system at Red River Army Depot. The systems received 15 months of green chemical treatments. Results from this project have been included in a pending draft rewrite of UFGS-23 64 26 Chilled, Chilled-Hot and Condenser Water Piping Systems.
AR-F-317: **Pipe Corrosion Sensors at Fort Bragg** The objective of this project was to implement in-situ sensors that continuously monitor potable water corrosivity and piping corrosion. These sensors measure several water quality parameters and assess corrosivity so that water treatment can be tailored to current conditions. In addition, linear polarization resistance sensors measure actual pipe corrosion rates. The data provided by these two sensors help pinpoint problems and the effectiveness of corrosion control can be monitored and quantified. Sensors were installed at critical locations in the water distribution system at Fort Bragg. These sensors can be applied DoD-wide at any installation with a potable water system. They can also be used by the government to provide monitoring and oversight of privatized and contractor-operated water systems. Results from this project have been included in a pending draft rewrite of UFGS-33 11 00 Water Distribution
AR-F-318: **Ice-Free Cathodic Protection Systems for Water Storage Tanks at Fort Drum** The objective of this project was to implement ice-free cathodic protection systems to mitigate corrosion inside potable water storage tanks in cold climates. These cathodic protection systems are comprised of ceramic-coated wire anodes and a flotation and support system. This protects these cathodic protections systems from ice damage and the interior of the tank will be continuously protected from corrosion damage. This technology was installed in two elevated water storage tanks at Fort Drum during this project. It can be applied to all DoD elevated water storage tank facilities where ice formation can occur in the winter. Results from this project have been included in pending draft rewrites of UFC 3-570-02 Cathodic Protection Design and UFGS-26 42 15.00 10 Cathodic Protection System–Steel Water Tanks.
AR-F-319: **Corrosion Resistance Materials for Water and Wastewater Treatment Plants at Fort Bragg** (2005) The objective of this project was to implement advanced materials selection for water and wastewater treatment plants. Advanced materials selection guidelines used at potable water treatment plant and the wastewater treatment plant to provide: (1) alternative composite materials, (2) restoration coatings for deteriorated concrete in filter tanks and flocculation tanks (potable water treatment plant, (3) corrosion resistant metal alloys, (4) and UV resistant protective coatings for steel, such as moisture cured urethanes. This project was implemented at Fort Bragg. Results from this project have been included in UFGS-08 13 73 Sliding Metal Doors.

Table D-1. List of Corrosion-Related D, CPO–Funded Projects

2005 cont'd
AR-F-320: **Surface Tolerant Coatings for Aircraft Hangars, Flight Control Tower, and Deluge Tanks at Fort Campbell** (*2005*)
The objective of this project was to implement surface tolerant coating technology on steel structures. This technology allows for an overcoat to be applied to an existing deteriorated coating with minimal surface preparation. It included moisture curing polyurethane coating and new fluroropolymer coatings. This technology was applied to one flight tower, two hangars and two deluge tanks at Fort Campbell. Results from this project have been included in a pending draft rewrite of UFGS-09 90 00 Paints and Coatings.
AR-F-321: Remote Monitoring and Cathodic Protection Upgrades at Fort Carson (2005)
The objective of this project was to implement remote monitoring and cathodic protection upgrades at Fort Carson. The existing cathodic protection systems were upgraded using new ceramic anodes and drive-by remote monitoring of corrosion-related variables (such as corrosion potentials and current for cathodic protection system rectifiers and test stations. This technology was implemented on five water reservoirs and pipelines: 30 miles of water distribution, 40 miles of natural gas, two miles of natural gas, two miles of fire suppression, and five miles of stream line. Results from this project have been included in a pending draft rewrite of UFGS-26 42 15.00 10 Cathodic Protection System–Steel Water Tanks.
AR-F-322: **Cathodic Protection of Hot Water Storage Tanks Using Ceramic Anodes at Fort Sill** (2005)
The objective of this project was to implement technology with the capability to mitigate corrosion that occurs in hot water storage tanks. The technology utilized in this project is comprised of impressed current cathodic protection (ICCP) systems that use new ceramic anodes. This project implemented ICCP for six 1,000-3,000 gallon hot water storage tanks and linings and sacrificial anodes for 17 smaller (37-1,000 gallon) hot water tanks and heaters at Fort Sill. Results from this project have been included in a pending draft rewrite of UFC 3-570-02 Cathodic Protection Design.
2006
FAR01: **Electro-Osmotic Pulse Technology** (2006)
The objective of this project is to employ electro-osmotic pulse (EOP) technology to combat water seepage through concrete walls and floor in ammunition storage igloos in an effort to reduce corrosion of munitions and equipment and improve the air quality in ammunition storage igloos. EOP technology mitigates water-seepage problems from the interior of affected areas without excavation. The project was implemented at eleven ammunition storage igloos at Fort A.P. Hill, Virginia.
FAR02: **Smart Fluorescent and Self-Healing Coatings** (2006)
The objective of this project was to demonstrate and validate advanced smart-fluorescent and self-healing coating technologies in operational environments. When built into the primer and topcoat, these coating technologies can indicate where the coating has been damaged and self-repair the damaged areas. This project was applied to the Central Vehicle Wash Facility (CVWF) at Fort Bragg, North Carolina. Results from this project have been included in a pending draft rewrite of UFGS-09 90 00 Paints and Coatings.
FAR03: **Green Water Treatment** (2006)
The objective of this project was to design, install and operate environmentally friendly–also called "green"–inhibitor formulations and smart monitoring and control systems. This was done in an effort to improve the reliability and reduce the cost of operating and maintaining heating and cooling towers. Green formulations are biodegradable and nontoxic, can be disposed of safely and inexpensively, and are produced with minimal negative environmental impact. These formulations are biodegradable and nontoxic. They can be disposed of safely and inexpensively, and are produced with minimal negative environmental impact. Green water treatment and smart control were implemented at Fort Wainwright, Alaska and the U.S. Military Academy at West Point, New York on a total of five heating and eight cooling systems. Results from this project have been included in a pending draft rewrite of UFGS-23 64 26 Chilled, Chilled-Hot and Condenser Water Piping Systems.
FAR04: **Remote Corrosion Sensors for Detection of Corrosion on Mission Essential Structures** (2006)
The objective of this project was to demonstrate remote corrosion rate sensors. These sensors provide corrosion rate measurements that can reveal areas of structure that need immediate maintenance and which ones will need future maintenance. Because of this, an optimal maintenance schedule can be developed. These corrosion rate sensors are resulted in service life extension of the structure, and lower lifecycle cost, due to early detection and correction. This technology was applied to mission critical structure, such as C4ISR facilities and roofing of a motor pool at Okinawa. Results from this project have been included in a pending draft rewrite of UFGS-09 90 00 Paints and Coatings.

Table D-1. List of Corrosion-Related D, CPO–Funded Projects

2006 cont'd
FAR11**: Innovative Thermal Barrier Coatings** (2006) The objective of this project was to apply thermal barrier coatings to piping in heat distribution systems (HDS) manholes in order to prevent heat loss, improve safety for maintenance workings, protect steel piping, and create a less corrosive environment. This project utilized liquid ceramic coating which has been used for over ten years in industrial settings. The coating was applied to newly constructed, bare manhole piping. This technology was applied to ten or more manholes at Fort Jackson, South Carolina. Results from this project have been included in a pending draft rewrite of UFGS-33 60 01 Valves, Piping and Equipment in Valve Manholes.
FAR13: **Coating System for Corrosion Prevention and Fire Resistance for Metal Structures** (2006) The objective of this project was to apply a coating system to metal structures in order to prevent corrosion and provide fire resistance. The performance of the coating system was monitored over a one-year period to validate this technology for use across the DoD. The technology utilized in this project involves new, innovative, epoxy intumescent coatings that contain nano-corrosion inhibitors and can prevent steel from weakening when exposed to high temperatures. These coatings require virtually no maintenance and can withstand extreme environmental conditions. The coating system was applied to one hangar and one additional structure at the Rock Island Arsenal, Illinois. Results from this project have been included in UFGS-07 81 00 Spray-Applied Fireproofing.
FAR15: **Development of Corrosion Indices and Life Cycle Prediction** (2006) The objective of this project is to provide a basis for planning corrosion prevention and control by establishing rates of corrosion and impact of corrosion damage in specific environments. A downloadable software package will use previously collected data on the corrosive effects of different types of environments on equipment and facilities to assign a corrosion index to a given site based on environmental data. The corrosion index will allow the user to select appropriate corrosion resistant materials, coatings, cathodic protection, and water treatment for use in project specifications and maintenance practices. This project will be applicable to all DoD installations.
FAR16: **Corrosion Prevention of Rebar in Critical Facilities** (2006) The objective of this project is to apply concrete rehabilitation migrating corrosion inhibitor and cathodic protection compound to prevent corrosion of rebar and deterioration of concrete in critical facilities. The technology utilized in this project is comprised of a migrating corrosion inhibitor and an zinc-rich sacrificial coating that can be sprayed, brushed or rolled onto a concrete surface to protect rebar and mitigate deterioration of concrete. An electrochemical reaction between this compound and steel rebar causes the coating to oxidize slowly over many years while providing corrosion protection to the concrete surface below. This project will be applied to the fuel patrol bridge and a girder ring of a warehouse in Okinawa.
FAR20: **Ceramic Anode Upgrades** (2006) The objective of this project was to upgrade ceramic anodes in a potable water storage tank and install cathodic protections systems on underground natural pipelines. Installation also included cathodic protection test stations with remote monitoring systems that alert base maintenance personnel of potential problems. These cathodic protection systems consisted of deep well ceramic tubular anodes. They protect surfaces such as the exterior of steel pipes buried in the soil and the interior of potable water storage tanks from corrosion damage. This project was installed on a two million gallon potable water storage tank and underground natural gas distribution piping in the severely corrosive environment at Fort Jackson, South Carolina. Results from this project have been included in a pending draft rewrite of UFGS-26 42 15.00 10 Cathodic Protection System–Steel Water Tanks.
FAR21: **Sustainable Materials Replacement** (2006) The objective of this project is to renovate an existing building with sustainable material systems to document their performance, economic, and environmental benefits. It will also help develop engineering guidance documents to enable others to design and use these innovative material systems. This project will utilize commercially available, sustainable building product systems which are more resistant to corrosion and materials degradation than traditional materials. These systems include structural insulated panel wall systems, "green" concrete, high-performance roofing, insulating additives for paints, recycled wood, recycled thermoplastic lumber, recycled carpets, bio-fiber reinforced composites, bio-based cements, hi-performance floor coatings, and synthetic exterior wall claddings. A WWII-era Chapel at Fort Lewis, WA, will be transformed into an Environmental Education and Conference Center using these materials as a showcase of sustainable materials and design.

Table D-1. List of Corrosion-Related D, CPO–Funded Projects

2007
F07AR01: **Corrosion Resistant Non-Metallic Materials for HDS Piping** (2007) The objective of this project was to assess the thermal performance and corrosion condition of two versions of the installed new heat distribution systems (HDS) piping design. The results of this work quantify the working performance of these two versions of the new HDS design for both corrosion resistance and heat loss. For the installation, this will provide an assessment of their direct buried HDS piping. In a larger sense, the results will influence future procurements of HDS piping within DoD. Results from this project have been included in a pending draft rewrite of UFGS-33 61 13 Pre-Engineered Underground Heat Distribution System.
F07AR03: **Corrosion/Degradation Monitoring Technology for FRP Composites** (2007) The objective of this project is to monitor Fiber Reinforced Polymer (FRP) composite seismic upgrades at Michie Stadium (West Point) in order to predict their long-term degradation rates, based on short-term non-destructive testing. It is expected that this project will show the utility of composite corrosion/degradation monitoring system as effective real-time monitors of composite patch degradation and debonding rates, allowing the prediction of composite lifetime.
F07AR05: **Corrosion Detection and Management System for Potable Water at Fort Drum, NY** (2007) The objective of this project was to provide a developed, full-spectrum computer-based system that has the ability to predict and manage corrosion, and automatically deliver corrosion inhibitors as needed in potable water distribution systems. The system includes a dynamic water distribution system chemical and hydraulic simulation and diagnostic/management system that is interfaced with corrosion sensors and automated chemical injection via a Supervisory Control and Data Acquisition system. The system analyzes the data to provide continuous and automatic, installation-wide, automatic detection and diagnosis of corrosion and water corrosivity problems. This technology is applicable to any DoD installation with a potable water distribution system, including those systems that have been privatized or are operated by contractors. Results from this project have been included in a pending draft rewrite of UFGS-33 11 00 Water Distribution.
F07AR07: **Advanced Acoustic Leak Detection** (2007) The objective of this project was to demonstrate a low cost tool to detect corrosion induced leaks in critical portions of fuel distribution piping systems. Sensors were installed to listen for leaks and will transmit a leak status to the collection unit. This project demonstrated a passive acoustic leak detection system that will be permanently installed at Fort Carson. The detection equipment listens for fuel system leaks in approximately 20 critical locations. Training was also provided to installation personnel on the use of the system. Results from this project have been included in a pending draft rewrite of UFC 3-460-01 Design: Petroleum Fuel Facilities.
F07AR08: **Rehabilitation of Metal Roofing** (2007) The objective of this project was to examine a rehabilitation technology for corroded metal roofing. The solution to the roofing corrosion problem lies in the use of rehabilitation technology that uses roofing restoration coatings. The roofing rehabilitation coating is a single component, fast-curing polyurea compound formulated for rehabilitation of standing seam metal roofs. This project was applied at Wheeler Army Airfield, Wahiawa, Hawaii. Results from this project have been included in UFC 3-11-03 Roofing and UFC 3-330-02A Commentary on Roofing Systems.
F07AR10: **Long-life Thermal Spray Coatings for Metal Structures** (2007) The objective of this project was to thermally spray two above-ground fuel storage tanks (1 million gallons each) and the associated pipe fixtures at Fort Campbell, Kentucky to produce corrosion-resistant coatings of high thick-nesses and low porosity. These coatings are highly adherent and can protect the steel for more than 25 years. Two different types of spray coatings were used: Ethylene Acrylic Acid (EAA) polymeric coating on the piping fixtures, and zinc-aluminum alloy with a seal-coat on the fuel storage tank itself. Results from this project have been included in a pending draft rewrite of UFGS-09 97 13.26 Coating of Steel Waterfront Structures.
F07AR15: **Advanced Corrosion Resistant Steel for Fire Suppression Pipeline Rehab** (2007) The objective of this project was to implement innovative corrosion-resistant steel for the rehabilitation of critical utility systems such as fire suppression system pipelines. Judiciously chosen stainless steels, and innovative new steels (for example, a patented new processing technology called “Linterprocessing”) creates steel pipe with integral diffuse protective layers for superior corrosion resistant properties compared to regular carbon steel. This project was implemented at a fire suppression pipeline for Chinuwa-1 Fuel Tank Farm in Okinawa, Japan. Results from this project have been included in a pending draft rewrite of UFGS-21 13 26.00 40 Deluge Fire-Suppression Sprinkler Systems.

Table D-1. List of Corrosion-Related D, CPO–Funded Projects

2007 cont'd
F07AR17: **In-Situ Pipe Coating Technology for Fire Suppression System** (2007) Corrosion in the plumbing of fire suppression systems is a major concern, especially systems located in aircraft hangars. The five hangars at Fort Drum, New York use a three percent Aqueous Film Forming Foam (AFFF) system (required) which is highly corrosive. This project will use a liquid epoxy coating to line the interior of the fire suppression pipes in the fire suppression system in the hangars at Fort Drum with the worst problem. It is the intent of the Project Management Plan (PMP) to implement this corrosion prevention and control technology at multiple Army regions and installations in the future, as well as to other military service sites.
F07AR19: **Inherently Conductive Additives for Reducing Zinc Dust Content** (2007) The objective of this project was to apply a cathodic corrosion control coating on the exterior surfaces of a 300,000 gallon (42 ft. diameter) elevated water storage tank at Fort Bragg, North Carolina. The main goal of this was to improve reliability and reduce cost of operating and maintaining steel structures by using cathodic corrosion control coatings. This project incorporated two materials that are readily available and can easily be incorporated into epoxy paint formulations as a replacement for zinc dust. Specifications and standards will be developed for implementation of these conductive coating additives as a replacement of zinc-dust at other DoD locations. Results from this project have been included in a pending draft rewrite of UFGS-09 97 13.27 Exterior coating of Steel Structures.
2008
F08AR01: **Use of Reactive Vitreous-Coatings on Reinforcement Steel to Prevent Failure** (2008) The objective of this project is to address the concrete reinforcements used to support high capacity chillers to provide adequate cooling and humidity control for both worker productivity and corrosion control of electrical mechanical systems. The Army Corps of Engineers laboratory at ERDC-GSL has developed a new reactive silicate bonded to the steel reinforcement with a layer of vitreous enamel (porcelain) simultaneous steel to concrete bond that is 3 to 5 times stronger than the normal bond. This provides a durable glass coating that cannot delaminate and resists chemical attack better than any previous coating. This project will be applied to the foundation for the central high capacity chiller unit for Corpus Christi Army Depot.
F08AR02: **Corrosion Resistant Sustainable Self-Cooling Roof and Fiberglass Roof** (2008) The objective of this project is to evaluate advanced roofing technology application to help prevent corrosion. This project will address a corrosion problem that ranks in the top 25 highest contributors to the cost of corrosion. This project will utilize a self-cooling roof that employs corrosion resistant coatings with "cool" pigments, and uses an innovative ventilation system to reduce exposure to hot moist air. Also, fiberglass reinforced polymer roofs, which contains a fluoroplastic dispersion protective layer to protect against ultraviolet degradation.
F08AR06: **In-Situ Coatings for Steel Pilings** (2008) The objective of this project is to show the utility of repairing steel sheet pilings in various states of corrosion. The project will implement a coating technology that can be applied by a limpet/mobile cofferdam, which creates free access to the site. Through inspection, this optimum maintenance and repair works of steel surfaces below water in the dry, while minimizing disturbance to harbor activities.
F08AR07: **Composite Wrapping and CP for Pilings at Kawaihae Harbor, Hawaii** (2008) The objective of this project is to institute a hybrid system incorporating reinforced polymer composite wrapping in which ceramic anodes are included. After surveying design requirements and with Hawaii DPW approval (and Navy coordination as their part of the project), the composite wrap and CP system will be integrated and installed for full-scale demonstration and load and durability (corrosion resistance) testing. Laboratory testing and system modeling will be performed by both ERDC-CERL and NFEXWC/NAVFAC-Pacific.
F08AR13: **Remote Monitoring of Degradation of Reinforced Thermoplastic Composites** (2008) The objective of this project is to install wireless sensors and monitor the durability performance of a thermoplastic composite I-beam bridge. This project will also demonstrate and validate remote monitoring strain sensors and acoustic emission sensors on fracture critical steel bridges. This project will utilize thermoplastic I-beam designs and remote strain sensors. This will be accomplished through laboratory tests and monitoring, field sensor demonstrations and monitoring, and field load testing of materials and bridge structures.
F08AR14: **Photovoltaic Cells for CP of Pipes and Tanks** (2008) The objective of this project is to demonstrate the utility of cathodic protection of pipes and tanks from corrosion powered by photovoltaic cells. Implementation of this project will involve an initial assessment of pipes and tanks, identification of pipes and tanks which need cathodic protection, installation of photovoltaic cells powering cathodic protection, and a follow up inspection of installation at Pohakuloa Training Area, Hawaii.

Table D-1. List of Corrosion-Related D, CPO–Funded Projects

2008 cont'd
F08AR23: **EOP and Dehumidification Technologies in Ammunition Bunkers** (2008) The objective of this project is to eliminate water and high humidity in ammunition storage magazines, eliminate corrosion and equipment problems and potential problems associated with water intrusion and humidity in magazines, and improve the air quality within the magazines. This project will compare the effectiveness of dehumidification alone to keep the magazine dry and the interior air moisture between 40 percent and 50 percent with the effectiveness of EOP to do the same tasks and to compare the effectiveness of using both technologies together in the same magazine.
F08AR24: **Electrokinetic Remediation of Alkali Silica Reaction (ASR) in Concrete Pavements** (2008) The objective of this project is to eliminate pavement expansion and deterioration as a result of alkali silica reaction (ASR), extend the life of existing pavements, and reduce maintenance costs to maintain operational capability at the airfield. This project will utilize moisture sensors–which will be installed in the pavements to record changes in humidity–to verify the moisture reduction. Any changes in the pore ion content will also be monitored as an indicator of potential ASR activity. An Electro-Osmotic Pulse (EOP) system will be installed in 15,000 square feet of taxiway at Campbell, Kentucky.
2009
F09AR02: **Corrosion Resistant Fences and Railings** (2009) The objective of this project is to address severe corrosion on physical security fencing for restricted areas in coastal and tropical environments where the atmosphere is humid and laden with salt. Four types of fencing materials will be tested: (1) galvanized steel coated with fuse bonded PVC, (2) stainless steel with 18percent Chromium -8percent nickel by weight (AISI 304 alloy), (3) Galfan fencing comprised of a coating of 5 percent aluminum - 95 percent zinc by weight (which is metallurgically bonded to the steel core), (4) and fiberglass fencing. The corrosion rates of each of the four types of fencing materials will be compared with a new installed 50 foot section of the currently used galvanized steel fencing at Torii Station, U.S. Army Garrison, Okinawa.
F09AR03: **Robust Heat Distribution System (HDS) Manhole Sensors** (2009) The objective of this project is to implement sensors with the ability to withstand of extreme heat and humidity for extended periods of time for the purpose of remote monitoring of heat distribution system manhole conditions in order to assure timely repair response. The sensors for this project monitor the ambient temperature and water level in heat distribution system (HDS) manholes. These are variables that lead to corrosive conditions. The sensor technology will be demonstrated and validated at Fort Carson.
F09AR04: **Corrosion Resistant Roofs with Integrated Sustainable Photovoltaic Power Systems** (2009) The objective of this project is to use advanced roofing metals with corrosion resistant coatings to mitigate corrosion of metal roofs–specifically roofs provide protection from tropical rains and the hot and humid outdoor environment for mission essential equipment, spare parts and maintenance equipment. This project will demonstrate an integrated corrosion resistant metal roof and photovoltaic solar cell system using an appliqué made of silicon solar cells which is bonded to corrosion-resistant roofing panels. The solar cells are connected to inverters and the power fed into the customer's electric grid. The integrated corrosion-resistant roof with silicon solar cell appliqué will be demonstrated at Kilauea Military Camp, Hawaii. A separate technology demonstration program was proposed to demonstrate an integrated photovoltaic membrane roofing system at Ft. Huachuca, Arizona that generates electricity while providing a long-lasting roofing membrane.
F09AR05A*: **Novel Additive for Concrete Structures Exposed to Salt Environments** (2009) The objective of this project is to develop a concrete material that resists crumbling from the effects of seawater, surf and wave erosion for concrete structures that are exposed to salt-water environments. Hycrete, the proposed material, is a hydrophobic concrete intended to bind the stones of seawalls and similar structures together and prevent sea water and chlorides from penetrating into the concrete. The technology has been requested by the U.S. Army Garrison, Hawaii, Directorate of Public Works, to help repair the PARC sea wall and prevent damage to constructed facilities *Congressionally funded project/No OSD Funding/OSD Oversight only

Table D-1. List of Corrosion-Related D, CPO–Funded Projects

2009 cont'd
F09AR5B*: **Integral Waterproofing for Concrete Structures, Research, Development, Evaluation and Demonstrations at IMCOM Facilities** (2009) The objective of this project is to provide waterproofing for all military construction where water migration through the concrete impacts the life and durability of the constructed facility—especially those concrete and reinforced concrete facilities in coastal zones. Hydrophobic concrete will be used to reduce water transport through the concrete wall panels and to prevent chlorides from attacking the reinforcement. The proposed hydrophobic concrete material is Hycrete. Facilities will be constructed at an Army and an Air Force installation using Hycrete additive incorporated into the concrete. *Congressionally funded project/No OSD Funding/OSD Oversight only
F09AR07: **Structural Health and Degradation Indices for Bridges** (2009) Structural Health Monitoring of bridges is used to evaluate the current condition of an existing structure and to detect changes such as crack growth, increased corrosion rates, or changes in bridge response to load. Several remote monitoring technologies will be used in the development of the indices, including corrosion rate, strain, displacement, vibration, tilt, and acoustic emissions. Fort Sill DPW and Fort Leonard Wood DPW have given a commitment to use two out-of-service bridges, one at each Installation, as a test bed in coordination with this proposed CPC project.
F09AR08: **High-Voltage Capacitor Based Water Treatment for Corrosion, Scale and Biological Growth** (2009) The objective of this project is to improve the effectiveness of water treatment to prevent scale deposition in evaporative cooling towers. Zeta Rod technology uses a very high voltage direct current to develop an electrostatic field to control the corrosion, scale and bio-fouling in cooling water systems. It replaces the entire chemical water treatment system with a high voltage electrode. This technology will be implemented at two cooling towers and two evaporative coolers at Fort Huachuca and Fort Irwin. It will also be installed on two cooling towers and two evaporative coolers at Air Davis Monthan and Warner Robins Air Force bases.
F09AR10: **Improved Zinc Dust Primer and Coating System for Steel Structures** (2009) The objective of this project is to provide an anticorrosion coating primer with improved performance and durability that provides the ability to retard the spread of corrosion at discontinuities such as pinholes, holidays or breaks in coatings. This coating system is based on paint additives designed to inhibit corrosion by forming both a high-quality barrier film and a cathodic protection coating that does not require the high pigment loading of a traditional zinc-rich primer. A product formulated with this coating system will be selected to coat the exterior surfaces of a steel structure, such as a potable water tank at Wheeler AAF.
F09AR12: **New Generation of Corrosion Resistant Fire Hydrant Retrofits** (2009) The objective of this project is to provide reliable corrosion resistant fire hydrants at DoD facilities. The system that will be utilized in this project, The Davidson System retrofit, will replace corrosion prone stems and other internal components will with new generation stainless steel stems and inner workings that are corrosion-resistant. This retrofit will be demonstrated on existing fire hydrants at Ft. Leonard Wood.
F09AR13: **State of the Art Reinforcing Bar for Concrete Structures** (2009) The objective of this project is to demonstrate and evaluate reinforcing bar technologies for prevention of corrosion of reinforcing bars in concrete structures exposed to alkaline or other highly corrosive environments. Two technologies will be assessed: (1) MMFX 2, a novel reinforcing steel that is low in carbon, chromium, and micro-composite steel; (2) Nuovinox™ ('NX') is a stainless steel clad composite product with a carbon steel core. The technology has been requested by the U.S. Garrison Hawaii to help reduce their maintenance and replacement costs of their sea wall and other coastal concrete structures.
F09AR14: **Innovative Corrosion Resistant Coatings and Materials for Pumps** (2009) The objective of this project is to provide corrosion resistant steel housings and advanced metallic coating systems on new water pumps for wash facilities. The technology utilized in this project involves coating pump impellors and housings with a cobalt-based alloy called "Stellite" using the High Velocity Oxy Fuel (HVOF) process. Corrosion resistant pumps will be installed and evaluated at Fort Polk.

Table D-1. List of Corrosion-Related D, CPO–Funded Projects

2009 cont'd
F09AR16: **Lightweight Fiber Reinforced (Thermoset) Polymer Composite Bridge Decks** (2009) The objective of this project is to demonstrate and validate state-of-the-art and emerging innovative technology approaches for rehabilitating failed concrete bridge decks using fiber reinforced polymer (FRP) composite systems. Fiber reinforced polymer (FRP) bridge deck systems are systems of composite materials that are pre-engineered and fabricated in manufacturing facilities. The materials have high strength and stiffness achieved by using environmentally resistant vinyl ester or polyester resin reinforced with E-glass fibers. An existing roadway bridge at Redstone Arsenal having a steel girder substructure that has a reinforced concrete deck experiencing severe corrosion of the steel reinforcement will be selected for this demonstration. The concrete deck will be demolished and replaced with a corrosion resistant prefabricated lightweight FRP composite bridge deck and wearing surface.
F09AR17: **Dilute Flowable Backfill Validation for Corrosion Mitigation of Buried Piping** (2009) The objective of this project is to reduce corrosion of underground pipe systems due to corrosive soil by using a high pH value dilute flowable backfill to entirely encase buried piping. Flowable backfill is a low compressive strength concrete that is designed to reduce pipe corrosion. This technology will be implemented and evaluated at Ft. Hood.
2010
F10AR01: **Corrosion Resistant Coatings for Air Conditioning Coils** (2010) The objective of this project was to demonstrate and validate high-efficiency, cost effective coatings to protect chillers and air conditioning coils and fins and vehicle condenser evaporator coils and fins from corrosion. This project utilized a cathodic polymeric electro coat (e-coat) technology for corrosion protection of heat transfer surfaces. The outcome was the elimination of corrosion and corrosion products in air conditioning coils in Hawaii and condenser evaporators in vehicles. Updates to UFC 3-410-01 FA Heating, Ventilating, and Air Conditioning, and TM 5-810-1 Mechanical Design Heating, Ventilating, and Air Conditioning, will be prepared and submitted based on project results. Updates to Marine Corps vehicle O&M manuals will be prepared and submitted through Navy channels.
F10AR02: **Innovative High-Performance Concrete Floor Sealants** (2010) The objective of this project was to demonstrate fluid-applied concrete coating/sealant using nanoparticles of ceramics, industrial grade diamond, silver, and glass. These nanoparticles were custom blended in a solution of water or alcohol for the surface to be treated. Based on the results of this effort, updates will be made to UFGS 09 90 00 Paints and Coatings and UFC 3-190-06 Protective Paint and Coatings.
F10AR04: **New Mold Mitigation Technology for Buildings** (2010) The objective of this project is to demonstrate a novel approach to mold and fungus management that will mitigate both the medical biohazard and the biodegradation of structural materials, finishes, and furnishings. Three antimicrobial coatings/surface treatments have been selected for demonstration under this project to protect construction materials from premature degradation due to mold and decay fungi growth while protecting the health of building occupants. This project will be implemented at Ft. Polk.
F10AR06: **Accelerating Natural Cementation for Road Stabilization** (2010) The objective of this project is to demonstrate and validate an emerging state-of-the-art innovative technology for stabilizing the surfaces of unpaved road using alkali-activated glassy silicates and silicate-rich by products. This project will demonstrate the use of natural glasses such as volcanic ash and glassy byproducts such as ground slag and fly ash reacted with sodium carbonates, silicates, and lime to make a hard, dust-free road surface. This technology is applicable to unpaved roads and other traffic areas on all DoD facilities
F10AR07: **Moisture Control Using Intelligent Single-Well Electro-osmotic Dewatering Systems** (2010) This objective will be a field demonstration of the use of the Morefield, McInerney, Hock et al. patent (U.S. Patent 7,135,102, Nov. 14, 2006). This technology uses electrodes distributed on a single non-conductive well casing to produce a directed current into the soils surrounding the well and produce dewatering without the installation of multiple electrodes.
F10AR08: **Vinyl Paint for Cold Locations** (2010) The objective of this project is to demonstrate the performance of a new coating system for steel structures. This coating technology will provide military installations with improved options for selecting low-maintenance, high-durability coating materials that require less frequent application and, therefore, less disruption of military vehicle traffic associated with repainting operations. This project will be demonstrated on Bailey Bridge during cold temperatures.

Table D-1. List of Corrosion-Related D, CPO–Funded Projects

2010 cont'd
F10AR12: **Corrosion-Resistant Bonding Enamel-Coated Steel Fixtures in Masonry Wall Construction** (2010) The objective of this project is to demonstrate a prototype application of new glass-ceramic coated hardware for use in brick/block masonry construction. This new coating contains a reactive calcium silicate layer that reacts with the water in surrounding mortar to produce a hardware/mortar bond that is typically two to three-times stronger than the bond between mortar to bare steel. The glass enamel coating on the steel also protects the hardware from corrosion.
F10AR13: **Intelligent, Nano-Technology Sol-Get Corrosion Sensor System** (2010) The objective of this project was to develop and demonstrate the use and benefits of an intelligent, sol-gel based corrosion sensor embedded with nano-/micro-electronics. It also demonstrated the innovative sensor system as part of structural health monitoring system on Government Bridge, Rock Island Arsenal, IL. The sol-gel sensor underwent both lab and field testing. Guidance to be modified: TM 5-600 (Bridge Inspection, Maintenance, and Repair); AR 420-72. Transportation Infrastructure and Dams.
2011
F11AR04: **Geopolymer Soil Stabilization and Dehumidification** (2011) The objective of this project is to demonstrate and validate the benefits of integrating dehumidification and an emerging state-of-the-art soil stabilization alternative floor slab system for engineered tension fabric structures that serve as long term storage and maintenance facilities for Army equipment and vehicles. This geopolymer technology uses glassy byproducts and native soil to provide a foundation with the required properties. A humidity controlled 10,000 sq. ft. tension fabric structure at Army Strategic Logistics Activity Charleston South Carolina will be constructed to demonstrate this technology.
F11AR08: **Portable Electrochemical Impedance Spectroscopy** (EIS) **Coating Sensor** (2011) The objective of this project is to demonstrate and validate the benefits of a coating health monitoring system (CHMS) based on electrochemical impedance spectroscopy (EIS). EIS is a proven technique to measure the condition of a coating which, before now, was mainly used for laboratory investigations in immersion service. Advances in electronics and miniaturization of components now bring this technique to the field. This innovative portable health monitoring system will add a useful tool for condition-based management of coatings on critical facilities and structures. The sensor is capable of mobile communications for virtual monitoring and inspection. The portable EIS coating health monitoring device will be used to measure coating conditions of coatings implemented under past CPC Projects at Fort Bragg, NC (storage tanks, piping, aircraft hangers, and roofing), Fort Lewis, WA (roofing and water tank) and Wheeler Army Airfield, HI (roofing).
F11AR15: **Metallic Membrane Technology** (2011) The objective of this project is to demonstrate the metal membrane technology described in U.S. Patent 7,284,357 (McInerney, Morefield, Hock, et al., 23 October 2007). A new type of moisture barrier for concrete slabs is patented bonded metal membrane that represents a significant improvement over current sealing technology. This system completely blocks moisture movement through pore spaces and fractures in concrete. Army and DoD facilities experience the problem of water intrusion in on-grade and below-grade concrete and masonry structures. Moisture through concrete slab-on-grade construction is a serious problem that can reduce the service life of a building and can even it the unsuitable for human habitation or storage of equipment and supplies due to mold propagation.
F11AR24: **Concrete Liner System** (2011) The objective of this project is to demonstrate and validate an innovative corrosion prevention and control technology for wastewater treatment plants. This multi-layered polymeric lining system is designed for manhole, wet well structures and wastewater treatment plant (WWTP) structures. These layers work together to form a multi-layer stress-skin panel that will extend the service life of the materials. This technology will be tested on components of the wastewater treatment plant at Ft. Lewis, Washington. Candidate surfaces include concrete walls of digesters, grit chambers, and head-works. The results will be documented in a technical report, and applicable guide specifications and criteria documents will be updated to facilitate DoD-wide implementation.
F11AR25: **Missile Storage Facility** (2011) The objective of this project is to demonstrate the capability of dehumidification technology to reduce the relative humidity enough to extend the mission readiness of sensitive critical missile systems in long term storage in tropical and other hot, humid locations used for forward positioning. This project will be implemented at Kadena Air Base, Okinawa.

Table D-1. List of Corrosion-Related D, CPO–Funded Projects

2011 cont'd
F11NV09: **Energy Harvesting Power Module** (2011) The objective of this project is to design and test a self-powered energy harvesting power module for a recently developed cathodic protection system rectifier remote monitoring unit (RMU). This project will develop a power module that harvests energy from the cathodic protection line directly by tapping into the DC voltage leads at each monitoring station. The module will consist of an electrical circuit to charge a robust capacitor or small rechargeable battery to provide power to the RMU. Successful integration of the power module with the commercial RMU will be installed and evaluated for the fuel storage and distribution cathodic protection system located in Guam, where the RMU's with lithium batteries are currently being field tested.
2012
F12AR01: **Fiber Reinforced Polymer Composite 3D Grid** (2012) The objective of this project is to demonstrate and validate state-of-the-art and emerging innovative technology approaches for rehabilitating failed steel reinforced concrete structures using a fiber reinforced polymer (FRP) composite 3-D grid as the reinforcing element for the concrete. Because FRP composites are not susceptible to the corrosion, they can last longer than conventional steel reinforced concrete materials in this highly demanding application. This technology is applicable to bridges throughout the tri-services. This technology will be demonstrated on a roadway bridge at Fort Knox, Kentucky.
F12AR03: **Assured Impressed Current Corrosion Protection** (2012) The corrosion of ferrous structures (e.g., piping and storage tanks) is a significant and ongoing expense on Army and Department of Defense (DoD) installations. Corrosion is the number one cause of damage to industrial waste lines, potable water distribution lines, heat distribution piping, and underground fuel storage tanks. The proposed CPC demonstration will develop a standardized technology consisting of (1) a field-portable instrument that can be expediently used to collect essential electrical potential and current data and (2) software capable of analyzing and then extrapolating the data to give a fast and accurate representative estimate of the structure's ultimate equilibrium polarization. Six water towers at Ft. Leonard Wood will be tested for CP using the prototype device that is created.
F12AR06: **2-Coat High-Performance Coating System** (2012) Two different two-coat coating systems were be applied to exterior-exposed steel structures located at Ft. Bragg, North Carolina. By eliminating the labor and materials required for the application of an intermediate coat, significant savings can be realized. Based on the results of this effort, updates will be made to UFGS 09 90 00 Paints and Coatings (May 2012), UFGS 09 97 13.27 Exterior Coatings of Steel Structures (Feb. 2012) and UFC 30190-06 Protective Paint and Coatings.
F12AR07: **Condition Based Corrosion Prediction Model for Fuel Distribution** (2012) The objective of this project is to develop a condition performance model for underground fuel supply, return lines and bottom of the storage tanks in order to provide a state-of-the art product capable to predict the remaining life of the pipes and storage tanks, maintenance and repair needs. The preliminary steps towards this particular effort will include: the identification of the critical parameters, exchange of information with model experts and algorithm maturity, validation of the product—analysis of actual field conditions (excavation/dig ups at Ft. Campbell, Kentucky) and incorporation of the condition performance model into the FUELER SMS. The scientific model will be based on an initial survey to generate static corrosion data under current conditions and the analysis of corrosion coupons that will be buried underground for 3-6 months at pipe depth.
F12AR11: **Corrosion Inhibitive Organic-Based Dust Palliatives** (2012) The objective of this project was to demonstrate and validate the benefits of a unique soil binder (RhEPS) in combination with organic humectants for dust control. From a safety standpoint, helicopter brownouts are an immediate concern and inhalation from repeated exposure to siliceous and other fine dust may pose delayed health problems for personnel. Maintenance costs due to dust damage to vehicles and the corrosive salts used to control dust on roads are significant. Also, fugitive dust transported by wind from Army installations may be a concern for nearby residents, civilian and military. Criteria Document to be revised: UFC 3-260-17 Dust Control for Roads, Airfields, and Adjacent Areas, (Army TM 5-830-3 Air Force Manual AFM 88-17, Chap. 3)

Table D-1. List of Corrosion-Related D, CPO–Funded Projects

2012 cont'd
F12AR12: **Self-Repairing Coating** (2012) The objective of this project was to demonstrate and validate the benefits of an innovative self-repairing polyurethane coating for infrastructure application. This self-repairing mechanism is based on the incorporation of reactive functional groups within the polymer network. The technology was applied to hangar doors that are subject to mechanical abuse at the Corpus Christi Army Depot, Texas. Updates will be developed for UFGS 09 90 00 Paints and Coatings (May 2012) and UFC 3-190-06 Protective Coatings and Paints.
F12AR14 Vapor-Phase Coatings (2012) The objective of this project was to demonstrate and validate the benefits of a coating that incorporates a vapor-phase corrosion inhibitor (VCI). A VCI in a coating prohibits corrosion at both the cathodic and anodic sites on steel by stabilization of the primary oxide film. A VCI coating can be applied to both concrete and steel surfaces. The vapor phase coating were applied to hangar doors that are subject to mechanical abuse at the Corpus Christi Army Depot, Texas. Updates will be developed for UFGS 09 90 00 Paints and Coatings (May 2012) and UFC 3-190-06 Protective Coatings and Paints.
F12AR15 Hybrid Composite Bridge Beams (2012) The objective of this project is to demonstrate and validate hybrid composite bridge beams. Corrosion of steel is the major cause for deterioration of both steel and reinforced concrete bridge beams. Hybrid composite beams combine the strength and stiffness of conventional concrete and steel with the lightweight and corrosion advantages of advanced composite materials. The hybrid composite beam will be demonstrated on an existing roadway bridge at Fort Knox that is experiencing severe corrosion.

Table D-2. ONR, AFRL, and Other Research/Lab Agency–Funded CPC Projects

Characterization of MIC Organisms in In-Ground Fuel Storage Tanks (AFRL/RXAS) In-ground jet fuel storage tanks are known to become contaminated with microbes. A subset of these microbes may be capable of causing corrosion, known as microbially influenced corrosion (MIC). Using Applied Research (6.2) in-house funding, AFRL is characterizing the microbial population in fuel tanks from corrosive vs. non-corrosive environments, to determine if there is a causative relationship between certain species and MIC. The results of this study will influence the design of materials and sensors to mitigate causative agents.
Bio-Deterioration of Materials in Biofuels: Evaluation and Research (BOMBER) **Program** (AFRL/RXAS) The material susceptibility of fuel infrastructure materials exposed to alternative fuels was previously evaluated by AFRL/RXAS. Jet fuels are known to be susceptible to microbial growth, and newly certified alternative fuels support a different microbial population than those found in Jet A or JP-8. It is also known that microbes can cause deterioration of polymers and metals. Using Applied Research (6.2) in-house funding, AFRL is evaluating the susceptibility of fuel infrastructure materials, including those used in in-ground fuel storage tanks, to microbial populations found in contaminated alternative fuel blends. Microbial biofilms removed from bio-deteriorated materials will be evaluated for their microbial content, to determine which microbes cause damage to a particular material. The results of this study will inform the AF of potential impacts due to the introduction of alternative fuels. (Characterization of MIC Organisms and BOMBER Programs sections provided by Air Force.)

Table D-2. ONR, AFRL, and Other Research/Lab Agency–Funded CPC Projects

Floating Double Deck Hybrid (Modular Hybrid Pier) (ONR/NAVFAC)

The Floating Double Deck Pier (FDDP) developed a pier design that could be built offsite, deployed and be assembled on site, disassembled and be redeployed again. As the project progressed, the goal was to develop a floating double deck pier that is modular, reconfigurable, minimize piling by over 60 percent, reduce seafloor footprint by over 50 percent and provide a 100-year service life for waterfront concrete structures to reduce maintenance, construction, and demolition costs. In order to accomplish that goal, a broad array of corrosion related challenges had to be addressed and resolved.

Achieving a 100-year service life is a function of quality aggregate, mixture design, and concrete cover. Examples of corrosion prevention lessons learned include the founding shaft, which replaces piles for structural stability, is dipped in a passivated bath and cathodic protection is utilized to protect the submerged surfaces of the shaft regardless of the material choice. The secondary shaft steel pipe pile that was driven into the seafloor pipe pile was coated with a corrosion-preventing glass flake epoxy (developed by NAVFAC EXCC) and passively cathodically protected by two 93-pound aluminum anodes. The Test Bed was also outfitted with current flux and voltage potential sensors that have the capability to monitor corrosion behavior and protection of electrically isolated post-tensioning hardware, other concrete reinforcement, and the founding shafts. The electrical resistivity of well cured high volume fly ash concrete is considerably less than required to prevent corrosion of the reinforcing steel.

The following technologies were transitioned as a result of FDDP:

- High Strength Light Weight Concrete (HSLWC): Concrete mixture used 33 percent Class F fly ash as a partial replacement for Portland cement. Pre- and post-stressed reinforcement in two directions to ensure crack closure. UFGS 03 31 29 changes now allow use of slag and fly ash at 50 percent replacement to Portland cement.
- Service Life Modeling: NAVFAC EXWC developed a novel methodology to predict the long-term service life of marine concrete using state-of-the-art multi-mechanistic finite element software, STADIUM®. D, CPO Project F10NV10 demonstrated this technology. Other projects that benefited from the methodology predicting service life (STADIUM®) include Navy FDDP, many piers, dry docks, and wharves as well as the third lock of the Panama Canal, U.S. Department of State facilities, and various public works and commercial projects.
- Major changes to UFGS 03 31 29 Marine Concrete were implemented to allow users to specify performance of the structures in terms of service life and the tools provided to verify during construction.
- Designing structures using the guidelines provided in UFGS 03 31 29 will result in greater readiness and more sustainable development, as corrosion of the steel is the number one cause of premature failure of reinforced concrete in marine environments.

The FDDP project was supplemented with D, CPO funds for corrosion monitoring in FY06 (Project FNV04 Modeling of Advanced Waterfront Materials) and for the use of high volume fly ash in concrete in FY09 (Project F09NV07 High Volume Fly Ash Concrete).

ASTM Code and Specification Changes

The waterfront research discussed in the previous paragraphs resulted in changes being made to ASTM A934/A934M-07 Standard Specification for Epoxy-Coated Prefabricated Steel Reinforcing Bars. NAVFAC EXWC (Engineering and Expeditionary Warfare Center) lead an ASTM International subcommittee to develop a new industry standard for fusion-bonded epoxy-coated steel reinforcement–which was tailored to provide extended service life for Navy waterfront structures. Coated steel does not provide an adequate replacement for good design and placement of quality concrete with appropriate concrete cover. When a contractor fails to use good concrete and proper cover, which often happens, the use of fusion bonded steel reinforcement has proven itself to extend the service life of the structure significantly.

Alkali Silica Reactivity (ASR) **Research** (NAVFAC)

The objective of Alkali Silica Reactivity (ASR) Research is to develop a fundamental understanding of what causes ASR in concrete and how it can be mitigated. The EXWC is working with three research institutions (two universities and one private) this year to establish acceptable limits for extended performance of concrete

A larger test sample can show that an aggregate is reactive even after a smaller test sample may show that it is not. ASR can be mitigated with the use of Class F Fly Ash and other natural pozzolans. As a result of this research several papers have been submitted for peer reviewed publications. The results will also be used for refining the expansion limits in specifications.

Table D-2. ONR, AFRL, and Other Research/Lab Agency–Funded CPC Projects

High Performance Airfield Pavements—JSF Pavements (ONR/NAVFAC) High Performance Airfield Pavements (HPAP) research was executed with the intent to develop a material that would be able to sustain the elevated temperatures and pressures that a Joint Strike Fighter would subject a pavement to during a vertical landing (VL). After one vertical landing, asphalt pavements melt and current concrete airfield pavements have a high probability of spalling. A concrete mixture can be produced which can sustain more than 500 simulated vertical landing cycles. The concrete needs to have aggregates formed at high temperatures and fibers, with a topical sodium silicate coating once the concrete has cured. Several proprietary materials have also been tested and shown capable of withstanding the high temperatures and pressures. Thus far information has been transitioned to three different bases with five vertical landing pads and a simulated carrier deck. ◆ Concrete mixes with two different lightweight aggregates have been made ◆ A concrete mix with a Basalt Trap Rock will used by the end of FY13 ◆ At MCAS Yuma the VL pad is currently being used by AV-8B aircraft prior to the arrival of the JSF
PAVER Micro PAVER software is a pavement management program that complies with ASTM D6433 and ASTM D5340. These standards provide information in identifying all types of pavement distresses and calculate pavement condition. These pavement distresses can be grouped into three groups; Climate, Structural, and Other related distresses. The climate related distresses provide information about pavements corroding due to weather and/or oxidation of asphalt pavements. Micro Paver can be used to identify the best pavement candidates for global surface treatments to mitigate further degradation of the pavements; thus preserving and extending the life of the pavements. In the GSB-88 Study done by NAVFAC EXWC, Micro PAVER was used to identify pavements sections to apply GSB 88 and measure the increase of pavement condition, which translate an increase life of the pavements.
Ceramic-Coated Anode ERDC developed a breakthrough mixed metal oxide (MMO) ceramic-coated anode design as an alternative to silicon-iron and graphite anodes. This patented design makes corrosion protection available at one-half the life-cycle cost for previous technologies, and its smaller size permits installation in every application within the cathodic protection (CP) industry. These anodes feature a unique arc-plasma sprayed surface architecture, which makes them the most abrasion-resistant MMO anode available.
Recycled Plastic Lumber Recycled Plastic Lumber materials from high-density polyethylene are inherently resistant to degradation of moisture, rot, and insects. Working with industry and academic partners, ERDC led development of seven ASTM standard test methods and specifications. These materials have been used in ERDC-led demonstrations for 15 years, with each one advancing the performance and developing new applications - the most recent of which was a bridge design that could support an M1 Abrams tank. D, CPO Project F08AR12 was utilized to demonstrate this technology. F12 funding had been received from USACE to develop criteria supporting the use of this technology.
Corrosion-Resistant Reinforcing Steel ERDC developed and pioneered the use of reinforcing steel that is coated with a special glass enamel coating which consists of an inner layer of alkali-resistant glass with a layer of Portland cement fused to the outer surface. This patented coating consistently triples the bond strength between concrete and steel, prevents corrosion of steel, extends life of structure, and reduces costs. D, CPO Projects F08AR01 AND F10AR12 were utilized to demonstrate this technology. Criteria change documents UFC 3-250-04FA, Standard Practice for Concrete Pavements, and UFC 3-301-01, Structural Engineering, are under development to reflect the discoveries from this technology.
Water Distribution Models with Sensors Localized corrosion and water quality problems have been an ongoing problem for Army installations. ERDC engineers have integrated several technologies to develop a complete corrosion detection and management system. A small number of sensors feed into a SCADA and the resulting “living model” provides a complete and near real-time picture of a water system.

Table D-2. ONR, AFRL, and Other Research/Lab Agency–Funded CPC Projects

Guy Crawler Inspection Tool (SIBR) The Guy Crawler Inspection Tool was developed to detect and identify hidden corrosion on guy wires for all large guy-supported structures (e.g. Fixed Submarine Broadcast Systems). It was learned through demonstration and development of the system that visual inspection of the guy wires is not efficient and/or guarantees that critical corrosion will be found. The tool, once fully developed will provide a repeatable and more efficient way to identify corrosion and the results from the inspection will help to develop a replacement schedule of the guys based upon corrosion and useful life of the guy. This technology is being transitioned for final development via Office of Naval Research Rapid Innovation Funds (RIF). If successful, this tool and methodology could be utilized for life-cycle support and inspection for large guy wires. The antenna guy wire tool SBIR project was also demonstrated using D, CPO funds (projects FY06 FNV06 and FY09 FNV09).
Splash Zone Coating (SBIR) The splash zone is the waterfront area from low tide to 10 feet or more above high tide depending on local conditions. It has the highest rate of corrosion in a naturally occurring environment. The intent of this project was to replace the high VOC and environmentally hazardous systems currently in use with a coating system that would: a) be a low VOC non-hazardous coating system, b) provide longer than the typical 5 to 8 years in service life, c) be maintainable in the field, and d) be simple to apply. The EXWC has evaluated current alternatives; all had some limiting factors that lead to the need to develop a completely new alternative. The new coating system has zero VOC's, coal tar free, no hazardous materials including free of toxic metals, cures underwater for in situ maintenance, excellent bond to damp metal, exceeded solicitation requirements. The product is supported by two companies but the technology can be replicated by others so that competition will help keep the costs down. Service life is expected to exceed 20 years which is more than twice and up to 4 times current systems. The EXWC is transitioning via criteria updates to UFGS-09 97 13.26 Coating of Steel Waterfront Structures which are currently in development. The Splash Zone Coating was an SBIR project that transitioned to the Environmental Security Technology Certification Program (ESTCP) and was finally demonstrated with D, CPO funds in FY05 (Project N-F-221 Self-Priming Cladding (SPC) for Splash Zone Steel).
Interior Coating for Fuel Tanks (SBIR) The coating system for concrete tanks currently in use is difficult to apply, may not be successful, and the second system can have a short life span. No new concrete tanks are planned for construction but current ones must be maintained. The EXWC worked with industry to develop a system that could be used on both steel and concrete fuel tanks. The system has zero VOC's, greater adhesion and impact resistance than current systems, can be applied to concrete and steel substrates, but requires specialized equipment to apply. Service life is expected to exceed 50 years which is more than twice current systems. The transition strategy is to update criteria which are currently under development. These criteria include UFGS-09 97 13.15, Epoxy/Fluoropolyurethane Interior Coating of Welded Steel Petroleum Fuel Tanks, and UFGS-09 97 13.17, Three Coat Epoxy Interior Coating of Welded Steel Petroleum Fuel Tanks. UFGS-09 97 13.15 and 17 may be merged into one UFGS for all services.

Note: Navy projects provided by NAVFAC.

Table D-3. Examples of Non-DoD Government and Industry Corrosion-Related Technology Improvements

Technology and description	Impact/usability
Corrosion Research on Rock Bolts and Steel Sets for Sub-Surface Reinforcement of the Yucca Mountain Repository The purpose of this study was to understand environmental effects such as corrosion/oxidation of the support structure of the underground Yucca Mountain repository. In broad terms, research was conducted on two classes of materials: Rock bolts and Super alloys. It was prepared by the University of Nevada, Reno for the U.S. Department of Energy and the University Community College System of Nevada. Funding for this project was provided by the U.S. Department of Energy, Office of Civilian Radioactive Waste Management.	Benefits of this study include a better understanding of the corrosion rates of different steels and Alloy 22 in the Yucca Mountain Nuclear Waste repository. Many important findings for the Yucca Mountain project were discovered including the corrosion behavior of Alloy 22, HSLA steels, AISI-SAE 4340 steel, and high-temperature oxidation kinetics.
Reinforced Concrete Pipe Cracks—Acceptance Criteria The purpose of this project is to (1) determine the influential parameters responsible for crack healing in in-place Reinforced Concrete Pipes (RCP), (2) determine what may constitute a maximum crack with amendable autogenous healing and sufficient to mitigate reinforcement corrosion, and (3) formulate guiding models detailing pipe crack acceptance criteria during construction. This project was performed by the University of South Florida, Department of Civil and Environmental Engineering. Funding was provided by the Florida Department of Transportation.	A predictive model for corrosion development in cracked reinforced concrete pipe was formulated and applied to interpret the outcome of the laboratory corrosion tests. Acceptance crack width guideline models proposed for discussion

Appendix E
Best Practices

The Facilities and Installation Corrosion Evaluation study team invited facilities and infrastructure professionals from 30 installations (included in the FICE study report) to share their best corrosion prevention and control practices. The list provided in this appendix is not endorsed by OSD, but it is representative of ideas that have worked for individual installation F&I professionals. It is important to note that these best practices may not be consistent with current criteria. It is also important to note that these F&I professionals are doing the best job they can with extremely limited resources.

The study team's findings are segregated into seven categories. In many cases, these findings could easily be placed in multiple categories because they touch multiple areas.

Condition Assessment

- DLA-Energy-provided fuel line inspections (twice per year) have been effective. Only two leaks have occurred in the last 15 years, and those were the result of old and deteriorating piping. No other problems have been reported.
- For critical inspections, bring in an inspection team from the outside.
- The following inspections should be performed at set periods:
  - Water towers and structural—every 5 years
  - Cathodic protection—annually
  - Fuel lines—monthly
  - Scoping sewer lines and lining them where needed. This action eliminates leaks and underground water intrusions without having to go through the expense of digging up the lines.
  - Infrastructure assessments (PACAF)—annually
- Check water quality parameters (using a state-certified laboratory) quarterly. Installation of water quality control panels at different locations in the water distribution system have helped monitor and correct chemical feed issues relating to corrosion control.

- Monitor water usage to detect leaks.
- The Infrastructure Condition Assessment Program (ICAP) covers the condition of assets and condition index (CI), and is recorded in Maximo. This is also accomplished through scheduled routine preventive maintenance.
- Use a corrosion preventive maintenance team.
- Perform tank and boiler inspections yearly. At one time, an in-house inspection team accompanied by a maintenance team either fixed the deficiencies that were discovered or put in the work orders.
- Utilization of a door inventory program at an ammunition storage installation which helps assure blast, health safety, and security. The doors are assigned health codes.
- Conducting an Annual Fire Hydrant replacement program focusing on three types (down from 15).

Material Selection

- A version of corrosion prevention is material selection based on application. The following are examples provided:
  - Galvanized steel for hand rails.
  - Wood structures sealed once a year.
  - Replacement of culvert pipes (galvanized) with concrete.
  - Use of GSA pipe coating products.
  - PVC piping instead of copper when water is chlorinated.
  - The use of specific procedures when digging and borium lignite is discovered. Lignite will cause a more acidic environment when combined with water in the soil, which primarily affects bolts.
  - Painted concrete to prevent salt spray penetration.
  - Use of adhesives for tiles on a roof to avoid roof penetration.
  - Coating backup generator fan blades to prevent corrosion in highly corrosive areas.
  - Replacement of galvanized pipe with PVC culvert (but be aware that fire can cause the culvert to burn).
  - The use of nonmetallic piping as much as possible with tracer wire installed for all underground pipe.

- The use of materials based on application. The following are examples:
  - Carbon steel material used outdoors (fasteners, nuts, bolts, railings, etc.).
  - The use of stainless steel outdoors when possible (e.g., use of stainless steel base for transformers).
  - HDPE material for piping.
  - Use of zinc fencing.
  - Aluminum for chain link fencing (when security protocols permit).
  - Use of corrugated metal roofing.
  - Installation of stainless steel for fasteners, enclosures, ducting, and virtually any component for which a stainless steel option is offered.
  - Replacing underground storage tanks with aboveground storage tanks.
  - Stainless steel transformer, switch gear, and electrical boxes.
  - Use of an epoxy siloxane hybrid coating for casings on air conditioning units.
  - The use of aluminum coils and fins; application of aluminum pigmented polyurethane to HVAC coils for longer life.
  - The use of aluminum standing-seam roofs.
  - Avoiding steel/rebar on concrete runways; fly ash is added, which strengthens the concrete and doesn’t create any corrosion issues; dowels still connect the sections.
  - Use of polymer coatings in tanks.
  - The use of precast and pre-stressed concrete fender piles (instead of steel).
  - Replacing cyclone fence and around condensers with concrete in windy, high humidity areas.
  - The installation guide for Kwajalein requires the use of stainless steel, fiberglass doors and copper coils.
  - Constructing block buildings with baked-on finish window units; four ply built up roofing, or standing seam baked on coating metal roof for steep slopes complete with a warranty.

- Specify stainless steel or fiber glass for cooling towers.
- Procure coated fins in air conditioner units.
- Install phenolic coating on outside equipment in high humidity area.
- Sealed motors for PV array.
- Use “an epoxy ester rust preventative primer” and standardized metal roofing.
- Use aggregate for concrete shipped in to island locations rather than using highly corrosive coral.
- Use of algae inhibitors in runway stripping paints, especially in highly corrosive locations such as Guam.

TECHNOLOGY

- Using computerized tablets for inspections. Some sites have created and developed their own tablet inspection applications (i.e. internal asbestos tracking)
- Use of “oil-free” chiller compressors, which minimizes acid reduction corrosion.
- A laser alignment tool allows the installation to align the pumps and motors once a year, greatly extending their life.
- GPS is used to locate underground utilities and obstructions and the system is kept up to date. The Interim Work Information Management System shows this information.
- Smart metering technology installed with real-time monitoring capabilities.
- AFCESA has the Reach Back Center for posting technology developments.

PROCESSES AND APPLICATIONS

- Asphalt slurry seal every 3–5 years.
- The use of de-icing spray versus salt.
- De-icing chemicals cause corrosion in the valves in the petroleum collection pits. Current practice is to apply epoxy on the valves to reduce corrosion.

- Ensure project management practices for F&I projects and SRM activities.
- Use of stainless steel fasteners to replace corroded fasteners.
- Wood piles covered in plastic to minimize wood rot—ultimately replacing wood piling with concrete as a better material substitute.
- Implementation of water treatment program for HVAC systems.
- The use of plastic (versus metal) conduit where applicable.
- Leveraging the building manager program to ensure early identification of SRM requirements with a focus on accomplishing the highest priority work.
- Adequately insulating chillers to prevent water condensation and mold and mildew build-up.
- The leveraging of design-bid-build acquisitions to develop and enhance in-house design expertise.
- The replacement of old steel pipes with new pipes and apply tape wrapped cathodic protection (CP).
- Using high-density polyethylene (HDPE) for new sewer lines. (HDPE is also being investigated for gas lines as well. PVC is too brittle, where HDPE is flexible, strong, has low friction, and can take ground movement.)
- Using aggressive preventive maintenance programs that ensure early detection of deficiencies and reduce corrosion deterioration.
- Air-conditioned mechanical rooms and electrical sub stations reducing the exposure to salt spray and other corrosive risks. System reliability has increased as a result.
- Ultraviolet (UV) light treatment and dehumidification for HVAC to prevent mold and mildew. In high humidity areas install dehumidifier and UV protection with each AC unit to combat mold.
- The use of spray foam instead of batt insulation to prevent mold.
- The elimination or limiting of the source of water helps tremendously in resisting corrosion. Civil design criteria require a minimum 2-foot overhang beyond exterior walls. This aids in keeping the water away from the building envelope and therefore decreases water intrusion.

- Standard roof type is a hydrostatic (watertight) standing seam metal roof. Metal panels must be factory fabricated from hot dipped steel coil coated with 55 percent by weight aluminum–zinc alloy in a minimum application rate of 0.55 oz. per square foot, with an exterior finish of 70 percent polyvinylidene fluoride containing 100 percent inorganic pigments. Exterior metals (including soffit, fascia, gutters, downspouts, etc.) are required to have the same finish.

- Washing of condensers and fins (require copper fins and coils and stainless exterior shells). Previous life of non-copper coils was less than 2 years.

- Replacing transformers at very corrosive sites at the same time lights are replaced. (The transformers are enclosed which reduces corrosion and reduces energy usage.)

- Procuring transformers with enclosed switches.

- Installing transformers on pads and placing utilities underground in areas at risk for high winds (e.g. typhoons).

- Using high-density polyethylene over PVC. PVC can be too brittle in extremely cold climates with earth movement. High-density polyethylene gives flexibility, strength, low friction and some ground movement allowance.

- Using of automatic flush valves reduces chlorine levels in drinking water and water treatment is leveraged to reduce sulfuric acid content and the associated system deterioration

- Specify the addition of water softeners as a standard requirement for high water usage areas such as dining facilities

COMMUNICATIONS, TRAINING, AND PARTNERING

- Review and coordinate projects by a committee of public works design and maintenance, safety, environmental, and security to ensure projects are fully coordinated before release.

- Maintain a close relationship with industry partners who introduce new technologies.

- Keep a list of base deputies' emails; send out notifications of a problem or find a potential solution through information sharing.

- Send personnel to conferences/symposiums (such as the Lighting Symposium or the Snow symposium) to learn about new technologies. Although funds to attend symposiums are very limited, those who attend have better insight of the state of the art.

- Provide lessons learned from past projects to the project development team for the upcoming projects.
- Provide advance funding for service calls, when the organization is a tenant; ensure access to the host installation's work order system.
- Use a community of practice (COP) to communicate best practices or information to all facilities. A COP coordinated through the web (or discussion forums and phone conferences) can be useful when looking for more information regarding new technologies or to send out a message about a problem and asking if anyone knows the solution.
- Periodic meetings of groups are held to ensure sharing of important information. This practice allows for the exchange of information and reprioritization of some work, and includes fire and safety topic dialog with customers. These meetings are especially important with tenants and joint bases, which helps in the coordination of MILCON issues such as in the identification of demolition plans which might be listed for both services.
- Promote good intra-organizational relationships and communication.
- Incorporate training in the contract for new equipment and send mechanics to the factory for training.
- Record lessons learned into the specifications, change maintenance practices or provide feedback to the design agent. These specifications are the ones the DPW uses. Each champion keeps his specifications and details for his area. The installation performs design reviews specific to trade area. Constructability reviews are being performed and a single point of contact is provided. This practice includes management, engineering and design and utilities areas. Constructability reviews are done in the contract management and privatization branch (QA branch).
- The maintenance branch provides feedback on best practices for inclusion into new contracts.
- Recommend that maintenance charettes be held at the time of hand over which allows them to figure out everything they will need to do to maintain the building or project.
- IMCOM shares experiences and lessons learned on AKO Garrison Commander forum site.

POLICIES, CRITERIA, AND GUIDANCE

- Use UFGS 23 25 00, Chemical Treatment of Water for Mechanical Systems.
- Develop and use design guides for specific locations, such as Guam, Kwajalein, etc.
- In unique areas, like Alaska, local design codes and regulations are compared to the main UFC to account for snow and wind loads.
- Develop a project notebook, which shows the supplemental specifications the site needs or desires (e.g., oil-free compressors, certain types of chillers, building practices that need to be followed to avoid painting and deterioration).

ACQUISITION

- Use IDIQ contracts for painting, valve replacements, roofing with certified installers, etc. This allows quick contract award within hours (rather than two months if an ID/IQ were not available). Including lead abatement into painting contracts ensures workload will be accomplished more seamlessly.
- Have a feedback system on contractor performance.
- Contract out water treatment for HVAC and boilers.
- At an Army site the maintenance contractor notes latent defects and gives the design agent the information. For example, on a fire suppression system low point drains were positioned at really bad angles, now the design agent correct this problem in new designs.
- Documenting lessons learned and feeding these into specifications to make further improvements for mechanical systems in the areas of equipment selection and materials. This ensures that the best practices are followed in the next design.

Appendix F
Definitions

Acquisition: The acquiring by contract, supplies, or services (including construction) by and for the use of the federal government through purchase or lease, whether the supplies or services already exist or must be created, developed, demonstrated, and evaluated. Acquisition begins at the point when agency needs are established and includes the description of requirements to satisfy agency needs, solicitation and selection of sources, award of contracts, contract financing, contract performance, contract administration, and those technical and management functions directly related to the process of fulfilling agency needs by contract. (See FAR Part 2)

Acquisition planning: The process by which the efforts of all personnel responsible for an acquisition are coordinated and integrated through a comprehensive plan for fulfilling the agency need in a timely manner and at a reasonable cost. It includes developing the overall strategy for managing the acquisition**.** (See FAR)

Code of Federal Regulations (CFR): The codification of the general and permanent rules published in the *Federal Register* by the departments and agencies of the federal government.[i]

Construction Criteria Base (CCB): An extensive electronic library of construction guide specifications, manuals, standards and other criteria documents. It is published and updated continuously. The CCB contains the complete unabridged, approved, current electronic equivalents of more than 10,000 documents from all of the participating federal agencies. The CCB is an extremely effective tool for finding and using current, approved U.S. construction criteria.

Construction Engineering Research Laboratory (CERL): Part of the U.S. Army Engineer Research and Development Center (ERDC), which is the Army Corps of Engineers' integrated research and development (R&D) organization. CERL conducts research to support sustainable military installations. CERL also supports ERDC's R&D mission in civil works and military engineering.[ii]

Corrosion: The deterioration of a material or its properties because of a reaction of that material with its chemical environment. Traditionally thought of only as deterioration of metal (e.g., rusting of steel), but now expanded to include degradation of non-metallic materials as well. Some nontraditional examples include rotting of wood, degradation of concrete (carbonation, alkali-silica reaction phenomena), and degradation of composite materials due to reaction with the environment.

Corrosion prevention and control (CPC): The rigorous application of engineering design and analysis, quality assurance, nondestructive inspection, manufacturing, operations, and support technologies to prevent the start of corrosion, avoid functional impairment from corrosion, and define processes for the tracking and repair of corrosion problems. The following are CPC examples:[1]

- Application or repair of protective coatings to prevent exposure to the environment (not for aesthetics)
- Cathodic protection (including any periodic maintenance and testing efforts)
- Water treatment (including any periodic maintenance and testing efforts)
- Selection of materials (metallic and non-metallic) more resistant to corrosion (e.g., stainless steel, galvanized steel), metals other than steel (copper, brass, aluminum, anodized aluminum), and composite materials.
- Selection of materials to prevent dissimilar metal (galvanic) corrosion
- Corrosion allowance (e.g., specifying a thicker wall pipe for corrosion purposes)
- Specifying industry standard products that have built in corrosion control measures (e.g., NEMA 4X electrical enclosures)
- Periodic washing to remove salt deposits
- Design measures to prevent entrapment of water that will result in corrosion
- Use of corrosion inhibitors (grease on wire rope or other mechanical devices such as valve stems, etc.
- Additives in concrete to make it less porous to moisture and chloride migration. These provisions are included in marine concrete UFGS.

Cost avoidance: The calculated value of money saved based on an action taken in the present that is designed to decrease cost in the future.

Criteria: The overarching term of which specifications (among others) are a subset. The CCB is an extensive electronic library of construction guide specifications, manuals, standards, and many other essential criteria documents.[iii]

Deficiency: A condition that is considered to be sub-standard or below the minimum level of acceptability to meet a desired or required function or mission.

Design agent and **construction agent**: The individual (or organization: USACE, NAVFAC, etc.) that is responsible for the acquisition, funds allocation, and overall success of the design and construction process.

Design-bid-build (DBB): The traditional delivery method, in which design and construction are sequential and contracted for separately, with two contracts and two contractors. (See FAR Part 36)

[1] *Corrosion Prevention and Control Planning Guidebook*, Spiral 3, September 2007.

Design-Build (DB): Combining design and construction in a single contract with one contractor.

Discipline working group (DWG): A group of representatives from the DoD components who are responsible for the unification and maintenance of criteria documents. Each criteria document has a DWG assigned.

Early contractor involvement (ECI): A project delivery method in which the government engages the services of a general contractor to provide "preconstruction services" concurrent with a design effort. Construction is then done through a construction option on the ECI contract.

Engineer Research and Development Center (ERDC): Helps solve challenging problems in civil and military engineering, geospatial sciences, water resources, and environmental sciences for the Army, DoD, civilian agencies, and the public.[iv]

Engineering and Expeditionary Warfare Center (EXWC): A division of the Naval Facilities Engineering Command. EXWC provides specialized facilities engineering, technology solutions, and lifecycle management of expeditionary equipment to the Navy, Marine Corps, federal agencies, and other DoD clients. NAVFAC's Warfare Center represents the consolidation of the NAVFAC Engineering Service Center, the NAVFAC Expeditionary Logistics Center, the Specialty Center Acquisitions NAVFAC, and the NAVFAC Information Technology Center (ADCON).[v]

Environmental Security Technology Certification Program (ESTCP): DoD's environmental technology demonstration and validation program. The program was established in 1995 to promote the transfer of innovative technologies that have successfully established proof-of-concept to field or production use.[vi]

Environmental Severity Index (ESI): ESI is a scientifically developed index that facilitates comparison of the effects of an environment on materials. The two primary factors, which account for the measurement of corrosion, are the measure of moisture in the atmosphere and the measure of atmospheric chlorides. The ESI measurement used in the FICE study is based on the environmental effects on steel.

Facility: A building, structure, or linear structure out to an imaginary line surrounding a facility at a distance of 5 feet from the foundation that, barring specific direction to the contrary (such as a utility privatization agreement), denotes what is included in the basic record for the facility (e.g., landscaping, sidewalks, utility connections). This imaginary line is what is commonly referred to as the "5-foot line."

Facility analysis category (FAC): A classification of real property types within a "basic category," represented by a four-digit code. DoD FACs aggregate military department categories into common groupings based on commonality of function, unit of measure, and unit costs.

Facilities and infrastructure: Inclusive of facility categories 1–8 defined as all buildings, structures, and the basic underlying framework of real property in support of permanent installations required to support defense activities, including roads, airfields, surface and subterranean utility systems, fuel containment systems, pavements, and bridges. This excludes non-tangible assets (moveable equipment) and land facility category 9.

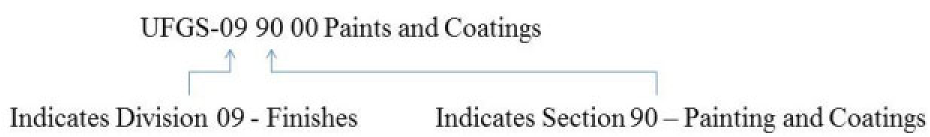
Guidance: Written guidelines that provide broad advice in following a procedure or process, instead of providing a set of precise requirements or standards that implements policy.

Historic asset: Historic properties, as defined by the National Historic Preservation Act, are those properties listed on, or eligible for listing on, the National Register of Historic Places (National Register). The National Register establishes specific criteria for the identification and evaluation of historic properties. (See 36 CFR 60.4)

Information Handling Services (IHS): A comprehensive database of non-government technical industry standards and government and military standards. The IHS also publishes a variety of reference books, manuals, and comprehensive guides.

Installation: A base, camp, post, station, yard, center, or other activity, including leased facilities, under the jurisdiction, custody, or control of the Secretary of Defense or the secretary of a military department or, in the case of an activity in a foreign country, under the operational control of the Secretary of Defense or the secretary of a military department, without regard to the duration of operational control. An installation may include one or more sites.

MasterFormat: A standard that is used for organizing specifications and other commercial and institutional building project–related information. Often referred to as the “Dewey Decimal System of building construction specifications.” It provides a master list of divisions, with section numbers and titles within each division. MasterFormat is used to organize UFGSs found in the *Whole Building Design Guide*. Example:



MILCON (military construction) program (as defined in 10 USC § 2801): “…any construction, development, conversion, or extension of any kind carried out with respect to a military installation, whether to satisfy temporary or permanent requirements, or any acquisition of land or construction of a defense access road (as described in section 210 of title 23)…A military construction project includes all military construction work, or any contribution authorized by this chapter, necessary to produce a complete and usable facility or a complete and usable improvement to an existing facility (or to produce such portion of a complete and usable facility or improvement as is specifically authorized by law).”

National Institute of Building Sciences (NIBS): A non-profit, non-governmental organization that brings representatives of government, professions, industry, labor and consumer interests, and regulatory agencies together to focus on identifying and resolving issues that hamper the construction of safe, affordable structures for housing, commerce, and industry throughout the United States.

Naval Facilities Engineering Command (NAVFACENGCOM): NAVFACENGCOM is the shore facilities systems command (SYSCOM) with Navy acquisition executive and head of contracting agency authority for facility planning, design, construction, services, utilities, facilities maintenance (public works), environmental, and real estate. NAVFACENGCOM manages the Department of the Navy (DON) shore facilities life-cycle. NAVFACENGCOM acquires and manages capabilities for the Navy's expeditionary combat forces, provides contingency engineering response, and enables DON energy security and environmental stewardship. (OPNAVINST 5450.34B)[vii]

National Institute of Standards and Technology (NIST): A non-regulatory federal agency within the U.S. Department of Commerce. NIST's mission is to promote U.S. innovation and industrial competitiveness by advancing measurement science, standards, and technology in ways that enhance economic security and improve our quality of life.[viii]

Office of Naval Research (ONR): Provides technology solutions to the Navy and Marine Corps through investments in science and technology research.[ix]

Painting Technology Center (PTC): Located at ERDC's Construction Engineering Research Laboratory (CERL), the U.S. Army Corps of Engineers' center of expertise for paints and coatings.[x]

Performance technical specification (PTS): Provide generalized technical requirements that apply to multiple facility types and include more requirements than are applicable to any one project. Therefore, only the RFP Part 4 requirements that apply to the project and further define the RFP Part 3 project-specific requirements are required. PTSs add clarification to the fundamental requirements section.[xi]

Policy: States the principles or goals of a DoD mission and defines performance standards and other means by which the DoD components can evaluate their success in implementing the policy. Policy statements are written concisely enough and in sufficient detail to ensure the policies are clearly articulated and to avoid the necessity of the DoD components having to prepare implementing or supplementing documents. This term is not normally used to denote what is actually done, but what is prescribed.

Procurement: The act of buying goods and services for the government.

Project: A specific procurement defined in contract specifications and documents. (See FAR Part 36)

Project management plan: A formal, approved document that defines how the project is executed, monitored, and controlled.

Quality assurance (QA): Government actions taken to ensure levels of quality are defined in the government contracts along with follow-on actions taken to ensure the government receives the appropriate levels of quality before acceptance of the work and approval of the contractor's invoices. (See FAR Part 46)

Quality control (QC): Actions taken by the contractor to ensure the quality of work delineated in the contract meets quality levels defined in the contract. (See FAR Part 46)

Request for proposal (RFP): Issued early in the procurement process, where an invitation is presented for suppliers (i.e., contractors) to submit a proposal to provide a service. RFPs allow the issuer to inform suppliers that an organization is looking to procure a service and encourages them to make their best effort, alert suppliers that the selection process is competitive, send out the request to wide distribution and response, ensure suppliers respond factually to the specified requirements, and use a structured evaluation and selection procedure so that an organization can demonstrate impartiality. The RFP process is generally thought to bring structure and organization to the procurement decision process. It is also meant to allow the risks and benefits to be clearly identified up front.

Research, development, testing, and evaluation (RDT&E): An appropriation used by the DoD to finance research, development, testing, and evaluation efforts performed by both contractors and government organizations in the development of equipment, material, or computer application software. This includes services (both government civilian salaries), equipment, components, materials, end items and weapons used in such efforts.[xii]

Resources: Factors required to accomplish an activity, or a means to undertake an enterprise. Most commonly referred to resources are labor and capital; other resources include land, energy, entrepreneurship, information, expertise, management, and time.

Return on investment (ROI): A performance metric used to evaluate the efficiency of an investment or to compare the efficiency of a number of different investments.

Simplified acquisition: Acquisitions of supplies or services that have an anticipated dollar value exceeding $3,000 ($15,000 for acquisitions as described in FAR 13.201[g][1]) and not exceeding $150,000 ($300,000 for acquisitions described in paragraph (1) of the Simplified Acquisition Threshold definition at FAR 2.101) are reserved exclusively for small business concerns and shall be set aside (see FAR 19.000, 19.203, and subpart 19.5). Note that this does not include acquisitions greater than $150,000, which would include military construction, special projects, and other large F&I projects.

Specifications: Specifications are made up of requirements that include UFGS, UFC, PTS, and others.[xiii]

Splash zone: The area between the year's lowest tidal mark and up to 10 feet above the year's highest tidal mark.

Subject matter expert (SME): An expert in a particular area or topic.

Sustainment: The maintenance and repair activities necessary to keep a typical inventory of facilities in good working order over their expected service life. Sustainment includes regularly scheduled adjustments and inspections, preventive maintenance tasks, and emergency response and service calls for minor repairs. It also includes major repairs or replacement of facility components (usually accomplished by contract) that are expected to occur periodically throughout the facility service life. This includes regular roof replacement, refinishing wall surfaces, repairing and replacing electrical, heating, and cooling systems, replacing tile and carpeting, and similar types of work.

Sustainment, restoration, and modernization (SRM): A program that provides funds to keep DoD's inventory of facilities in good working order (i.e., day-to-day maintenance requirements). In addition, SRM provides resources to restore facilities whose age is excessive or have been damaged by fire, accident, or natural disasters, and alterations of facilities to implement new or higher standards to accommodate new functions or mission.

Technical proponent: A representative from a participating organization responsible for coordinating the unification and maintenance of a criteria document. They may be a DWG member. Only a technical proponent can implement changes to a criteria document.

Technical representative: The author of a particular criteria document or the working-level representative from another participating organization for a particular document.

Technology (new or existing): Technical processes and products that represent innovations and progressive developments within a field.

Technology development: Technical processes and products, in the context of emerging technologies, that are not necessarily reflected in DoD criteria documents (UFGS, UFCs, etc.).

Unified facilities criteria (UFC): Documents that provide planning, design, construction, sustainment, restoration, and modernization criteria and apply to the military departments, the defense agencies, and the DoD field activities in accordance with USD (AT&L) Memorandum dated 29 May 2002. UFC are distributed only in electronic media and are effective upon issuance.

Unified facilities guide specifications (UFGS): Joint effort of the U.S. Army Corps of Engineers, the NAVFAC, the Air Force Civil Engineer Support Agency (HQ AFCESA), the Air Force Center for Engineering and the Environment (HQ AFCEE), and the National Aeronautics and Space Administration (NASA). UFGS are for use in specifying construction for the military services.

U.S. Army Corps of Engineers (USACE): The agency that provides engineering, design, and construction management to the Army. Its mission is to provide vital public engineering services in peace and war to strengthen our nation's security, energize the economy, and reduce risks from disasters.[xiv]

Whole Building Design Guide (WBDG): Managed by the National Institute of Building Sciences in Washington, DC. Content of the WBDG is a collaborative effort among federal agencies, private sector companies, nonprofit organizations and educational institutions. The WBDG was created to assist the design community with integrating government criteria, non-government standards, vendor data, and expert knowledge into a "whole building" perspective.

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[i] http://www.gpo.gov/fdsys/browse/collectionCfr.action?collectionCode=CFR
[ii] http://www.cecer.army.mil/td/tips/product/details.cfm?ID=458
[iii] http://www.wbdg.org/ccb/ccb.php
[iv] http://erdc.usace.army.mil/about-us/mission-vision/
[v] https://portal.navfac.navy.mil/portal/page/portal/navfac/navfac_ww_pp/navfac_navfacexwc_pp
[vi] http://www.serdp-estcp.org/About-SERDP-and-ESTCP/About-ESTCP
[vii] https://portal.navfac.navy.mil/portal/page/portal/navfac/NAVFAC_ABOUT_PP
[viii] http://www.nist.gov/public_affairs/general_information.cfm
[ix] http://www.onr.navy.mil/Science-Technology/ONR-Global/About-ONR-Global.aspx
[x] http://erdc.usace.army.mil/cerl/paint-technology-center-2/
[xi] http://ndbm.wbdg.org/system/html/6/451
[xii] https://dap.dau.mil/acquipedia/Pages/ArticleDetails.aspx?aid=e933639e-b773-4039-9a17-2eb20f44cf79
[xiii] http://www.wbdg.org/ccb/browse_lib.php?l=2
[xiv] http://www.usace.army.mil/

Appendix G
Abbreviations

ACAT	acquisition category
ACHP	Advisory Council on Historic Preservation
ACSIM	Assistant Chief of Staff for Installation Management (Department of the Army)
ADA/ABA	Americans with Disabilities Act and Architectural Barriers Act
ADA/ABAAG	Americans with Disabilities Act and Architectural Barriers Act accessibility guidelines
ADC (LF)	The Assistant Deputy Commandant for Facilities
A/E	architect/engineer
AF	Air Force
AFB	Air Force Base
AFCEC	Air Force Civil Engineer Center
AFCEE	Air Force Center for Engineering and Environment
AFCESA	Air Force Civil Engineer Support Agency
AFFF	Aqueous Film Forming Foam
AFI	Air Force instruction
AFRL	Air Force Research Laboratory
AFRL/RXSA	Air Force Research Laboratory/Materials Integrity Branch
AFRL/RXSC	Air Force Research Laboratory/Acquisition Systems Support Branch
AFRL/RXSS	Air Force Research Laboratory/Logistics Systems Support Branch
AFCEE	Air Force Center for Engineering and Environment
AFCESA	Air Force Civil Engineering Support Agency
AFI	Air Force instruction
AISI	American Iron and Steel Institute
AMC	Army Materiel Command
ANG	Army National Guard
ANGI	Army National Guard instruction

ANSI	American National Standards Institute
AR	Army Reserve
ARC	Army Reserve Command
ARNG	Army National Guard
ASA(CW)	Assistant Secretary of the Army for Civil Works
ASA(IE&E)	Assistant Secretary of the Army for Installations, Energy, and Environment
ASCE	American Society of Civil Engineers
ASHRAE	American Society of Heating, Refrigerating, and Air-Conditioning Engineers
ASR	Alkali Silica Reactivity
AST	aboveground storage tanks
ASTM	American Society for Testing and Materials
ATC	ambient temperature cured
ATFP	Anti-Terrorism Force Protection
BEAP	base exterior architecture plan
BEM	boundary element modeling
BOD	basis of design
BOS	base operating support
BRAC	Base Realignment and Closure 2005
C3PO WIPT	Corrosion Policy, Procedures, Processes, and Oversight Working Integrated Product Team
CAPT	captain
CBOD	Corrosion Board of Directors
CCB	Construction Criteria Base
CCPE	corrosion control and prevention executive
CDR	commander
CFR	Code of Federal Regulations
CHMS	coating health monitoring system
CI	condition index
CID	commercial item description
CJCS	Chairman of the Joint Chiefs of Staff
CJCSI	Chairman of the Joint Chiefs of Staff instruction
CMC	Commandant of the Marine Corps
CNIC	Commander, Navy Installations Command

COM MCICOM	Commander, Marine Corps Installations Command
COP	community of practice
COTS	commercial off the shelf
CP	cathodic protection
CPC	corrosion prevention and control
CPC IPT	Corrosion Prevention and Control Integrated Product Team
Cr6+	hexavalent chromium
CVWF	Central Vehicle Wash Facility
D, CPO	Director, Corrosion Policy and Oversight (DoD)
DAG	*Defense Acquisition Guide*
DASA(APL)	The Deputy Assistant Secretary of the Army for Acquisition, Policy and Logistics
DAU	Defense Acquisition University
DB	design-build
DBB	design-bid-build
DC IL	Deputy Commandant for Installation and Logistics
DCB	destruction criteria base
DFARS	Defense Federal Acquisition Regulation Supplement
DLA	Defense Logistics Agency
DoD	Department of Defense
DoDD	DoD directive
DoDI	DoD instruction
DON	Department of the Navy
DOT	Department of Transportation
DOTMLPF	doctrine, organization, training, materiel, leadership and education, personnel, and facilities
DPW	department of public works
DUSD(I&E)	Deputy Under Secretary of Defense (Installations and Environment)
DWG	discipline working group
EAA	Ethylene Acrylic Acid
ECB	engineering and construction bulletin
ECE	Electrochemical Chloride Extraction
ECI	early contractor involvement
EIS	electrochemical impedance spectroscopy

EMP	electromagnetic pulse
EOP	electro-osmotic pulse
EPA	Environmental Protection Agency
ER	electrical resistance
ERDC	Engineer Research and Development Center
ERDC-CERL	Engineer Research and Development Center—Construction Engineering Research Laboratory
ERP	enterprise resource planning
ESEP	Engineering Senior Executive Panel
ESI	Environmental Severity Index
ESTCP	Environmental Security Technology Certification Program
EXWC	Engineering and Expeditionary Warfare Center
F&I	facilities and installations
FAC	facility analysis category
FACD	functional assessment and conceptual design
FAD	Facilities Asset Database
FAR	Federal Acquisition Regulation
FDDP	floating double-deck pier
FDOT	Florida Department of Transportation
FEC	Facilities Engineering Command
F&I	facilities and infrastructure
FICE	Facilities and Installation Corrosion Evaluation
FISC	Fleet Industrial Supply Center
FRP	fiber reinforced polymer
FSRM	facilities sustainment, restoration, and modernization
FY	fiscal year
GFEBS	General Fund Enterprise Business System
GSA	U.S. General Service Agency
HDPE	high-density polyethylene
HDS	Heat distribution system
HEMP	High-Altitude Electromagnetic Pulse
HQ	headquarters
HQMC	Headquarters Marine Corps
HQUSACE	the United States Army Corp of Engineers
H.R.	U.S. House of Representatives

HSLA	high-strength, low alloy
HSLWC	high strength light weight concrete
HVAC	heating, ventilation, and air conditioning
HVOF	High Velocity Oxy Fuel
ICAP	Installation Condition Assessment Program
IDIQ	indefinite delivery, indefinite quantity
IEEE	Institute of Electrical and Electronic Engineers
IFS	Integrated Facility System
IHS	Information Handling Services
ILS	integrated logistics support
IMCOM	U. S. Army Installations Management Command
IPT	integrated product team
ISO	International Organization for Standardization
ISR	installations status reporting
JB	joint base
JCIDS	Joint Capabilities Integration and Development System
LCDR	lieutenant commander
LCSP	Life-Cycle Sustainment Plan
LEED	Leadership in Energy and Environmental Design certification
MCAS	Marine Corps air station
MCB	Marine Corps base
MCICOM	Marine Corps Installations Command
MCIEAST	Marine Corps Installations East
MCINCR	Marine Corps Installations National Capital Region
MCIPAC	Marine Corps Installations Pacific
MCIWEST	Marine Corps Installations West
MCLB	Marine Corps logistics base
MCO	Marine Corps order
MDACS	Marianas Design and Construction Standards
MILCON	military construction
MIPR	Military interdepartmental purchase request
MO	method of operation
MRACS	Marianas Region Architectural and Construction Standards

NAAMM	National Association of Architectural Metal Manufacturers
NACE	National Association of Corrosion Engineers
NAS	naval air station
NASA	National Aeronautics and Space Administration
NAVFAC	Naval Facilities Command
NAVFACENGCOM	Naval Facilities Engineering Command
NAVFACINST	Naval Facilities and Installations
NAVMC	Navy, Marine Corps
NDAA	National Defense Authorization Act
NFESC	Naval Facilities Engineering Services Center
NHPA	National Historic Preservation Act of 1966
NIBS	National Institute of Building Sciences
NIST	National institute of Standards and Technology
NRHB	National Registry of Historical Buildings
O&M	operations and maintenance
OEM	original equipment manufacturer
OICC	Officer In Charge of Construction
ONR	Office of Naval Research
OPNAV	Office of the Chief of Naval Operations
OPNAVINST	Office of the Chief of Naval Operations instruction
OSD	Office of the Secretary of Defense
OSHA	Occupational Safety and Health Administration
P.L.	public law
PMP	project management plan
PROSPECT	Proponent-Sponsored Engineer Corps Training
PTC	Painting Technology Center
PTS	performance technical specification
PVC	polyvinyl chloride
PWD	public works department
QA	quality assurance
QC	quality control
R&D	research and development
RAR	Rapid Action Revision
RBP	Release Prevention Barrier
RDT&E	research, development, test, and evaluation

RFP	request for proposal
RM	restoration and modernization
RMU	remote monitoring units
ROI	return on investment
ROICC	Resident/regional officer in charge of construction
SBIC	Sustainable Building Industry Council
SBIR	small business innovation research
SCADA	supervisory control and data acquisition
SE	systems engineering
SECNAV	Secretary of the Navy
SECNAVINST	Secretary of the Navy instruction
SHPO	state historic preservation office
SMDC	Space and Missile Defense Command
SME	subject matter expert
SPC	self-priming cladding
SRM	sustainment, restoration, and modernization
TMA	Tricare Management Activity
TOC	total ownership cost
TOW	time of wetness
TOW/S	time of wetness/salinity
TRL	technology readiness level
UF	united facilities
UFC	unified facility criterion
UFGS	unified facilities guide specifications
USACE	U.S. Army Corp of Engineers
USAF	U.S. Air Force
USAF/A7C	Air Force Civil Engineer
USAR	U.S. Army Reserve
USC	U.S. Code
USD(AT&L)	Under Secretary of Defense for Acquisitions, Technology and Logistics
USF	University of South Florida
USMC	U.S. Marine Corps
USC	U.S. Code
USN	U.S. Navy
UV	ultraviolet

VCI	vapor-phase corrosion inhibitor
VL	vertical landing
VLF/LF	very low frequency and low frequency
WBDG	*Whole Building Design Guide*
WIPT	working integrated product team
WWTP	waste water treatment plant

Annex
Military Department Comments

Representatives from across the military departments were provided an opportunity to comment on this report before its release. This greatly assisted the review by identifying errors and statements that required more clarification. The following reflects the military department–level comments *in toto*.

U.S. Army Comments

United States Army Comments on the Findings Identified in the Facilities and Infrastructure Corrosion Evaluation Study: Final Report

1. On 16 January 2013, the Secretary of the Army issued policy with the subject: Risk Mitigation in the Face of Fiscal Uncertainty. The following are excerpts that deal directly with facilities and infrastructure:

a. "The Army faces significant budgetary uncertainty in the coming months and must take immediate steps to reduce expenditures. We expect commanders and supervisors at all levels to implement both the guidance contained in this memorandum and the detailed instructions to follow. The fiscal situation and outlook are serious. Our funding is in doubt as we support forward-deployed troops, those training to deploy and Wounded Warriors. The uncertain Fiscal Year (FY) 2013 funding caused by the combined effects of a possible yearlong Continuing Resolution and sequestration, along with the need to protect wartime operations may result in particularly severe reductions to Operation and Maintenance spending."

b. "Seek to reduce base operating funding to achieve at least a 30% reduction of FY13 Base Operations Support spending levels compared to FY12 levels. To do so, commanders shall implement across-the-board efficiencies and reduce appropriated fund support for community and recreational activities, reduce levels of installation service delivery and reduce new and current contracts to minimum levels without incurring penalties. Commanders will reduce utility consumption to the maximum extent possible. Commanders who believe that this action would harm mission-critical activities should indicate their reasoning and propose alternate courses of action. To assist in implementing this initiative, the Assistant Secretary of the Army (Manpower & Reserve Affairs) will issue further guidance on the use of Soldiers to perform installation functions."

c. "Likewise, conference approval authorities shall further significantly curtail participation in conferences with exceptions only for mission-critical activities executable within the fiscal guidance published by the Assistant Secretary of the Army (Financial Management & Comptroller). This applies to all conferences whether or not previously approved."

d. "Cease facilities sustainment activities that are not directly connected to matters of life, health or safety. Additionally, cease all Restoration & Modernization projects, including Facilities Reduction Program and projects required to facilitate stationing decisions. Exceptions may be granted on a case-by-case basis, or where business decisions dictate, by the Assistant Chief of Staff for Installation Management."

2. The Army does not understand the distinction made in the report between "facility and infrastructure (F&I) personnel" and the "corrosion community", specifically where it is stated that the F&l personnel are not focused on corrosion.

a. Neither of these terms-F&I personnel and corrosion community-is defined in the report, and neither of them exists within the Office of Personnel Management (OPM) Handbook of Occupational Groups and Families, dated May 2009. Intimate knowledge of corrosion prevention and control (CPC) is not a requirement for any OPM job series that would likely be included under the umbrella of "F&I personnel," although general CPC knowledge may be inferred from the qualifications of the skills and knowledge required for some of these job series.

b. If the "corrosion community" is understood to include only those persons that participate in the Department of Defense (DOD) CPC Integrated Product Team (IPT), then it would be cost prohibitive and unreasonable to expect individual craftsmen from all DOD facilities to become part of this community.

3. The Army questions how the report represents training of the individuals that have responsibility for facilities and infrastructure.

a. Under the Defense Acquisition Workforce Integrity Act, one of the career fields that has specific education and training requirements is the Facilities Engineering field. The Defense Acquisition University specifies training and experience requirements for three different levels of Facilities Engineering certification. Employees identified as acquisition workforce members are required to meet the requirements of certification level associated with their position.

b. Training is a high priority within the Army, and any source of training is available to Army personnel subject to the availability and prioritization of training dollars, as determined by the commanding officer. However, there is insufficient evidence contained in this report for the Army to identify or verify any specific training shortfall suggested by the study team in its major findings.

c. Each employee of the Army (civilian or military) is required to prepare and negotiate with their supervisor the equivalent of an Individual Development Plan that identifies the desired future training requirements for that individual. For advancement within a specific job series, an individual has to show that they have the skills and knowledge to perform the duties of that position.

4. The Army is concerned over the finding that Army personnel are unaware of, or have misinterpreted policy and/or guidance in the execution of their duties.

a. The report did not specify which policies and guidance were not familiar to which level of personnel, nor which ones were not implemented correctly, in the eyes of the study team. Therefore, we are unable to determine whether corrective action is required.

b. The Army is aware of only two corrosion-specific policies that apply to facilities and infrastructure: DOD Instruction 5000.67 and Army Regulation 420-1.

c. The DOD and Army have official publication websites where all Army personnel can locate copies of these policies. In fact, many other official Army websites contain links to these publication sites.

d. It would be helpful to the Army if the study team would identify those policies and guidance documents referred to in the report. The report may be referring to the unofficial guides and training literature published on the CorrDefense website rather than official DOD and Army policy. As with any other unofficial reference material, these documents are freely available to Army personnel that seek to use them. Each organizational element in the Army chain of command has the authority to decide whether to promote, require, allow or disallow the use of such unofficial references.

5. The Army is concerned with the finding that communication is lacking with regards to CPC. The report does not provide sufficient information for the Army to determine any specific communications gaps that may exist.

a. The Army CPC Strategic Plan outlines a communication strategy that uses IPTs and Corrosion Prevention Advisory Teams to communicate CPC information up and down established Army chains of command. When necessary, policy and guidance are published down to the Army Commands, Army Service Component Command, and Direct Reporting Units, who are expected to distribute that policy and guidance to their subordinate elements.

b. At the present time, there is DOD and Army policy restricting conferences and meetings. Before this policy came into existence, the Army held an annual corrosion conference with participation by the Active Army, Army Reserve, National Guard, civilian workforce, and contractors. The policy has an obvious impact on department- wide communication, but the Army is mitigating the impact by increasing the frequency of e-mail, teleconference and other virtual communication methods.

c. The Army has access to a number of publications that can be used to communicate a specific topic to a much broader audience. These include, but are not limited to the following six items:

(1) Engineering Technical Bulletins

(2) Army Engineering Magazine

(3) Department of Public Works Bulletins

(4) Public Works Digest

(5) R&D Magazine

(6) American Society of Civil Engineers Magazine

6. The Army is concerned about comments suggesting that certain acquisition and procurement practices are not efficient or effective with regards to CPC.

a. It is unclear whether the report is simply documenting an observation about competing priorities and policies or suggesting that Congress, Office of the Secretary of Defense (OSD) and the military departments should take some action to modify existing statute, regulation, policy and practice.

b. The procurement practices in question- including performance based acquisition, standardization, competition, and small business programs- typically are established through statute, federal regulations and OSD policy, so the military departments and their procuring agencies are required to follow them.

7. The Army is concerned that the report doesn't fully recognize the Army organization for facilities and infrastructure.

a. The following organizations are part of the Army Secretariat:

(1) Assistant Secretary of the Army (Acquisition, Logistics and Technology. Only part of the facilities organization in the sense that the Army Corrosion Control and Prevention Executive is located in this organization.

(2) Assistant Secretary of the Army (Civil Works).

(3) Assistant Secretary of the Army (Installation, Energy and Environment).

b. The following organizations are part of the Army Staff:

(1) Office of the Chief of Army Reserves.

(2) Chief, National Guard Bureau.

(3) Deputy Chief of Staff, G-4.

(4) Chief of Engineers.

(5) Assistant Chief of Staff for Installation Management.

c. The Army Materiel Command is an Army Command.

d. The Space and Missile Defense Command is an Army Service Component Command.

e. The following organizations are examples of Direct Reporting Units:

(1) Installation Management Command

(2) Army Corps of Engineers

(3) Medical Command

Department of the Navy Comments

Concur without comment.

U.S. Air Force Comments

Concur without comment.

DEPARTMENT OF DEFENSE

UNITED STATES OF AMERICA