Government Coatings Research: Fundamental to Performance

by Cynthia Challener
JCT CoatingsTech
Contributing Writer

Coatings research activities within the U.S. Department of Defense and NASA address critical issues facing the military and upcoming space exploration initiatives. Corrosion detection and control, environmentally friendly/compliant technologies, and rapid cure topcoats lie at the center of many projects within the Army, Navy, Air Force, and NASA coatings research laboratories.

Recent studies regarding the impact of corrosion damage on U.S. industry and within the military highlight the need for effective control strategies and further research into prevention and detection technologies. In 2002, a study initiated by NACE International– The Corrosion Society found the total annual estimated direct cost of corrosion in the U.S. to be $276 billion—approximately 3.1% of the nation's Gross Domestic Product (GDP).

A 2001 government-sponsored study estimated the costs of corrosion for military systems and infrastructure to be about $20 billion annually. Corrosion was identified as one of the largest components of life-cycle costs for weapon systems and a major cause of downtime for critical military assets. The Government Accounting Office (GAO) report, "Defense Management: Opportunities to Reduce Corrosion Costs and Increase Readiness," issued in July 2003, found that the Department of Defense (DoD) and the military services do not have an effective approach to prevent and mitigate corrosion, despite the fact that each service has multiple corrosion offices.

The DoD has established a central corrosion control activity and strategy. The GAO recommended that the strategy should identify standardized methods for evaluating project proposals, estimating resource needs, and coordinating projects in an inter-service and service-wide context. The Office of the Secretary of Defense has initiated a concerted effort to fund corrosion research at the DoD and bring corrosion more to the forefront.

Currently, approximately $50 million is allocated annually for funding corrosion issues. Although significant increases in corrosion funding are difficult to achieve at this time, an increased emphasis has been placed on training and specification. The DoD will also benefit in the long-term from the incorporation of language into the defense federal acquisition regulations requiring that corrosion control shall be considered upfront in the procurement process, according to Keith Lucas, director of the Center for Corrosion Science & Engineering at the Naval Research Laboratory in

Shuttle photo courtesy of NASA.

Washington, D.C. The "corrosion exchange" within the DoD encourages the different government corrosion labs to work together and maximize their effort, eliminate duplication, and facilitate access to resources. It should also make it possible to put together larger research programs and make them more competitive with others seeking funding.

A separate, informal partnership has existed between the Naval Research Laboratory (NRL) and NASA for many years. The interagency agreement formalized the relationship between the two research groups and made it easier to share facilities and information and work on joint projects. Recently, both thought it could be highly advantageous to expand the agreement to include the other branches of the DoD and other related government groups. A document describing the agreement is currently circulating through the various chains of command.

As members of the "National Corrosion Technology Alliance," the participants will agree to collaborate together and pursue initiatives with the goal of enhancing the government's corrosion control capabilities and technology in order to meet national corrosion control needs, according to Dr. Luz Marina Calle, lead scientist for corrosion technology at the NASA Kennedy Space Center and a leader in getting the alliance established. The Army Research Lab's Coatings and Corrosion team leader and DoD CARC commodity manager, John Escarsega, believes that "this arrangement should formalize the process for both disseminating information to others and making inquiries as well. Identification of specific contacts within each research group will help us leverage the nation's resources and piggyback on one another's efforts."

The Kennedy Space Center (KSC) has been involved with corrosion research since the 1960s, when it began investigating coatings for the protection of launch structures. "The high salt content in the air, combined with the high heat and humidity and UV exposure levels makes for a very corrosive environment—one of the most corrosive in North America, if not the world," notes Dr. Calle. Shuttle launches add an additional 70 tons of hydrochloric acid from the solid rocket boosters to the mix, too. KSC's corrosion program, which began with exposure racks set up at the beach near the launch sites, now involves personnel and several facilities dedicated to R&D, testing, and development of maintenance procedures.

The current direction of NASA's coatings research is aimed toward meeting the needs of future space exploration missions. "We are preparing for new vehicles, launch pads, and other structures that will be required in the future. Corrosion in general is defined as degradation of material in a given environment. At NASA, we want to know how materials will degrade in extraterrestrial environments as well as here on Earth," Dr. Calle explains. "For example, on Mars, there is much greater UV radiation, and most likely brine solutions lie under the Martian surface. Both contribute to corrosion, and we must learn how to build spaceports and human habitats in such an environment." NASA is using simulation chambers to do just that.

Equipment to be used on exploration missions must be resistant to corrosion and require very little maintenance. If corrosion does occur, coatings will need "self-healing" properties to repair the damage at a very early stage and prevent any further failures. "We are very excited about how our research in corrosion control will be used for upcoming space exploration activities," says Dr. Calle. "We are going to have to look at coatings in ways we haven't done before, and develop new technologies to address these issues."

Multifunctional coatings with self-healing properties are also under investigation by the Air Force and the Navy. Most failures in aircraft occur in areas of high stress. "We are looking at the use of microencapsulated reactants (monomers, catalysts, etc.) as a way to repair minor failures immediately after they occur. When a scratch or void is formed, the reactants would be released and seal or fill the damaged areas," explains Stephen Szaruga, area manager for Specialty Materials with the Air Force Research Laboratory. His team is also exploring polymer self assembly, where monomers laid out on a surface polymerize under certain conditions to provide optical, corrosion, and health monitoring capabilities.

Early detection, particularly detection of corrosion underneath a coating, is a major goal for NASA and DoD. A current research focus at NASA concerns the development of "Smart" coatings that detect the presence of corrosion and release inhibitors as a response. The coatings will detect the change in pH that accompanies the occurrence of localized corrosion beneath the coatings. Corrosion inhibitors will then be released to arrest the process. According to Dr.

Calle, the research is at the very earliest stages. "At this point we are engineering the sensor aspect. The next stage will be to include it in a paint formulation."

Non-destructive evaluation (NDE) is a main research focus within the Air Force, too. "Aircraft are being kept in service for extended periods of time. There is a huge cost savings potential if we can find a mechanism for identifying corrosion underneath coatings," says Jeff Sanders, acting branch chief for the Air Force's Coatings Branch. Currently, coatings are stripped/removed off every five to seven years to allow for visual inspection of the aircraft. This process results in hazardous waste and means the aircraft is out of service for an extended period of time. "We are currently evaluating existing NDE techniques to inspect structures through the exterior aircraft coatings. Also under consideration is the incorporation of sensors or additives to the coating system that will assist corrosion sensors and NDE in detecting the presence of corrosion and level of adhesion under the surface of the coating. Our goal within 10 years is to be able to skip a depot cycle completely," says Mr. Szaruga. "The hard part won't be developing the technology, but demonstrating the efficacy of NDE to the structural community," he continues.

Photo courtesy of the U.S. Army.

Naval craft, too, are being kept in service for longer than ever. Longevity is a concern. The cost of inspecting tanks on a typical ship can be hundreds of thousands of dollars, in large part because of the procedures required to prepare for safe personnel entry. Research efforts at NRL are aimed at developing coating systems that require less maintenance and designing in-situ systems that monitor for corrosion and coating failure, according to Mr. Lucas. They are also investigating ways to conduct inspections mechanically by lowering optical scanners into the tanks, which will eliminate the need for costly preparation procedures. The Army, too, has ongoing projects directed at prevention and early detection of corrosion to maintain readiness and minimize equipment life cycle costs.

Another aspect of reducing costs is associated with the elimination of harmful substances from coatings. In general, NASA uses off-the-shelf, commercially available coatings that undergo extensive testing before receiving approval and incorporation into agency standards. Launch towers are typically coated with zinc rich primers and siloxane topcoats. Ongoing research projects include investigation of environmentally friendly alternative coatings and pretreatments that can replace coatings that contain volatile organic compounds (VOCs) and chromium. NASA is also looking at coatings for aluminum.

The Army is involved in developing chemical agent resistant coating (CARC) systems. At the Army Research Lab (ARL), three principles guide and assist scientists in the formulation, scale-up, and final implementation of new coatings in the field, according to Mr. Escarsega. The principles are: durability, environmental compliance, and survivability (which includes camouflage and chemical agent resistance). Topcoats are in general polyurethanes, primers are two-component epoxy systems, and pretreatments are predominantly hexavalent chromium-based. "Our coatings can be categorized as high performance industrial maintenance materials and really are in a class of their own," Mr. Escarsega notes.

Most recently, ARL developed a water-reducible two-component polyurethane CARC topcoat that will eventually replace the Army's standard two-component solvent-based system and can be used along with the current one-component solvent-based system. This will provide the Army with optimum choices depending upon the application and environmental compliance considerations, according to Mr. Escarsega. The water-dispersible polyurethane hybrid system reduces the VOCs by nearly 50% and eliminates hazardous air pollutants (HAPs) while actually possessing enhanced performance with respect to UV (a ten-fold improvement) and mar resistance and flexibility. The new topcoat contains hybrid resins with the attractive properties consistent with high performance polyurethanes. In

addition, the traditional diatomaceous silicas and talc used to reduce the gloss in camouflage coatings was replaced with polymeric beads.

"We have taken a new approach with our coatings systems," comments Mr. Escarsega. "Any material incorporated into a coatings formulation must have a function. We will no longer use extenders or fillers or other substances that do not contribute to the performance of the coating," he explains. The polymeric beads, which find wide use in automotive applications, act as an excellent flattening agent while simultaneously increasing UV and mar resistance and providing added flexibility. The Army's intent is to incorporate such technology into all of its existing topcoats for added performance, according to Mr. Escarsega. Additionally, ARL is evaluating self-contained and portable kits that will assist in waste minimization, field application, and touch up.

Both the Navy and Air Force are switching from traditional spray equipment to the plural component technology in use for commercial applications. The reduced amount of lines and hoses means quicker cleanup and reduced hazardous materials concerns, which, when combined, equal improved productivity and efficiency. "In the Air Force we need to work with established spray systems. Planes cannot be taken apart, put through an oven, or irradiated. Plural component technology allows us to use reduced amounts of solvent in a system that is comfortable for the guys actually applying the paint," says Mr. Szaruga. "This is especially important to the field units that need a rapid coating repair capability that enables them to return aircraft to active service."

Dramatic reductions in hexavalent chromium permissible exposure limits due to take effect in 2006 will affect the use of chrome in pretreatments and some primers. The Army does utilize chromium-free primers, but is currently in the process of evaluating chromium-free pretreatment/primer combinations. "Overall we are taking a new life cycle approach to coatings development," says Mr. Escarsega. "We are looking at both short-term performance capabilities and long-term recyclability issues."

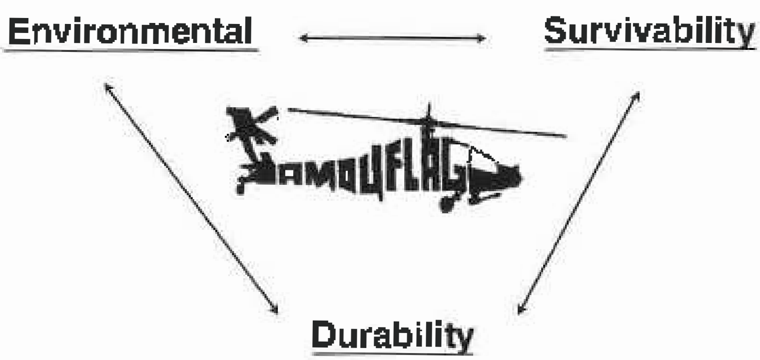
The Air Force, according to Mr. Szaruga, is about 80–90% of the way to developing a complete chromium-free system. "We have found chromium-free primers and pretreatments that work, but not together as a system. Each one requires chromium in the other component of the coating to make the system effective. I anticipate we will have a full chromium-free system that meets Air Force performance requirements within the next five years."

The Navy has the additional challenge of maintaining functional antifouling coatings, which have recently come under scrutiny by global regulatory agencies. "We removed tributyl tin from our antifouling coatings years ago and replaced it with copper-based antifouling agents," notes Mr. Lucas. As a result, the Navy has not been impacted by the recent ban on that particular substance. However, as others switch over to copper-based systems, there is a concern that copper levels in global waterways will rise to levels that trigger regulation of these actives as well. "The Navy management is very pro-active in this arena and we are currently investigating biocides and other technology as alternatives to copper-based antifoulants in our coatings in order to be prepared for any future changes in regulations," he further states.

The Coast Guard plays a major role in the testing program for antifouling coatings. "The Coast Guard has an excellent platform for testing antifouling coatings," says Mr. Lucas. "The Navy has a very symbiotic relationship with the Coast Guard. They provide us with the testing platforms at minimal cost and in return we share with them all results of new technology as it is developed."

With regard to VOCs, the Navy is addressing this regulatory issue as part of a program to develop 100% solids rapid cure coatings. Existing coating systems require roughly two weeks of application and cure time before the painted surface can be put back into service. The NRL has developed a resin that incorporates the anticorrosive properties of an epoxy with the rapid cure properties of polyurethanes. When formulated into a paint, the resin system possesses the benefits of both the epoxy (corrosion and chemical resistance) and the urethane (UV resistance and flexibility). "We are currently developing this technology for tanks, but envision it will have widespread applications for many surfaces. Drying time can be reduced significantly, and we hope to be able to spray out all coats in one evolution," says Mr. Lucas. He also hopes the technology will allow application of coatings at near freezing temperatures, which would extend the painting season to nearly year round. Currently the NRL is doing panel

Guiding Principles for Coating Systems



Courtesy of the U.S. Army.

tests and expects to conduct demonstrations in the near future. Mr. Lucas hopes to have a coating for actual use within the next three years.

Development of rapid cure topcoats for replacement areas (less than 100 square feet) on aircraft is also a priority for the Air Force. "Current military specifications require dry times of 72 hours, but there is no data to support the selection of this particular length of time," Mr. Szaruga comments. The Air Force is not only studying standard topcoats to determine minimal dry times, but is also investigating new polyurethane formulations and cure mechanisms in these applications.

Recent deployments to the Gulf have raised the issue of solar loading of vehicles, equipment, and ships. Both the Army and the Navy are involved in developing paint formulations with minimal solar loading. Minimization of UV light absorption should reduce the rate of degradation of these coatings and lower the temperature of surfaces on which they are applied. "Air conditioning systems on naval ships were not designed to withstand the heat that is common in the Gulf. We need all of the help we can get in reducing the heat load on the boats," notes Mr. Lucas.

Efforts at NRL include basic and fundamental as well as applied research projects. The group based in Washington, D.C., in addition to conducting laboratory corrosion and coatings formulations work, also liaises directly with System Commands and teams with other Navy labs. The Marine Corrosion Facility field site at Key West, FL, is ideally situated for marine engineering and testing. The waters around Key West are the closest approximation of "blue" oceanic waters to which naval ships are typically accustomed. The NRL has responsibility for a very broad array of coatings technologies, including anticorrosive and antifouling coatings for ship hulls, bilge coatings, and topside coatings for numerous types of tanks (potable water, sewage, ballast, fuel, etc.), interior decking, crew quarters, and non-skid landing deck on aircraft carriers, to name a few. For ships, there is also the added requirement for cathodic protection of underwater coated materials; the NRL also designs the corrosion protection systems for these applications.

In many cases, the results of R&D efforts within government coatings research labs get transferred back out to industry. Technology transfer is common at KSC. A latest example is technology for protecting rebar in concrete used for balconies and bridges. Rusting of the rebar occurs due to chloride intrusion from ocean or deicing salt. Expansion of the rebar as it rusts (rust has a larger volume than the metal) causes the cement to crack. NASA developed a galvanic coating that is applied to the concrete. The technology, which has been licensed to industry, protects the rebar underneath and prevents rusting.

In the Air Force, standard aircraft coating systems include a surface treatment, primer (typically epoxies, but some polyurethanes), and the topcoat (polyurethane). The Air Force uses five to six different colors of gray and creates low visual gloss in its paints usually through very high pigment loading. Deft, Inc. recently participated in a cooperative development project with the Air Force that resulted in a new extended life, high performance polyurethane-based gray paint. The new topcoat incorporates fluorinated components and exhibits an eight-fold increase in UV stability. According to Mr. Szaruga, the majority of the Air Force has switched to using this technology.

For its CARC topcoats, the Army is investigating several new technologies. "We are looking at both nanomaterials and enzymatic materials in novel coatings systems. These technologies can be utilized as sensors for detecting toxic agents. It may even be possible for them to act as reactors for decontamination processes. This type of technology would be easily extended to the commercial sector, especially for first responders," explains Mr. Escarsega.

Although coatings research is not what comes to mind when most people think about state-of-the-art technology being investigated by the military, it is clear that coatings do in fact play a fundamental role in determining the ultimate level of readiness and effectiveness of the armed forces. Research labs at NASA and the DoD are designing highly functional, environmentally friendly coatings that incorporate novel technologies to address critical issues facing vehicles, ships, aircraft, spacecraft, and many other types of equipment. These efforts will contribute to significant advances in the capabilities for defense, security, and space exploration.