



QuEST

Qualifying Environmentally Sustainable Technologies

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Message from the Principal Center Manager

The NASA Technology Evaluation for Environmental Risk Mitigation (TEERM) program has been in existence for twelve years. During that time, environmental issues facing NASA have continued to grow, increasing the risk to mission and continually challenging TEERM. The one thing that has not changed, however, is the company that provides TEERM support. ITB, Inc., based in Dayton, Ohio, has provided the engineers and support staff performing the TEERM task since the beginning in 1998 and has received a new five-year contract beginning FY 2010 that runs through FY 2014 enabling continued support.

As NASA's future continues to evolve with the times, so does TEERM's future. TEERM is determined to be a proactive part of the new vision for NASA. TEERM is looking to ease the transition from the Space Shuttle program by providing stability and continuity while maintaining focus in identifying and addressing priority environmentally-driven risks to the Agency.

TEERM's mantra of collaboration and consensus building continues to distinguish the program as an example of how to work complex issues with multiple customers. Our work continues to be of benefit to both the old and the new during this evolutionary phase and TEERM will continue to be an integral part of NASA's commitment to explore the universe in an environmentally sustainable manner.

Thank you,

Chuck Griffin

TEERM Principal Center Manager
NASA KSC/NE-I2

Collaboration Important to TEERM

NASA TEERM is responsible for helping NASA Centers and programs identify and assess environmentally preferable and sustainable technologies. TEERM activities comprise the areas of materials substitution, pollution treatment/control, renewable and alternative energy, remediation, green buildings, and encroachment issues, among others. Collaboration with end users and subject matter experts across NASA and elsewhere is a major component of TEERM projects. By TEERM's fostering of joint cooperation, project goals can be met more efficiently and economically. It enables TEERM to extend its impact and fulfill its mandate of reducing risks to NASA's mission from environmental drivers.

The specifics of TEERM partnerships can vary; but in general, they involve working together as a team on a project addressing common issues, with shared technical and financial responsibilities. In this type of partnership, participants share their knowledge of the current material or process and of the proposed replacements or solutions.

Advantages of Collaboration

Government agencies such as NASA face a challenging and changing work environment. Agency resources are limited and available funding is constrained. The testing required to validate environmentally preferable alternatives can be cost prohibitive for single customers. Fortunately, through collaboration with multiple stakeholders who share the same need, financial resources are made available in a leveraged manner to fully fund a project. Collaboration also reduces duplication of effort that might otherwise occur if individuals worked their problems alone. Validation of new technologies through partnerships leverages all participants' contributions to the project.

TEERM Partners

Within NASA, TEERM works closely with the Principal Center for Regulatory Risk Analysis and Communication (RRAC PC). The RRAC PC represents NASA interests to environmental regulators during rulemaking activities by identifying, analyzing, and communicating potential risks to the NASA mission from proposed, new, and existing regulations. Once a risk is identified, TEERM is a resource to help find solutions.

TEERM is also a member of the NASA Shuttle Environmental Assurance Initiative (SEA). SEA provides an integrated approach promoting environmental excellence, proactively managing materials obsolescence, and optimizing resources for the Space Shuttle Program. SEA members work together to exchange information and data on material replacement efforts, pollution prevention strategies, and potential environmental impacts. TEERM works with SEA to ascertain Space Shuttle Program needs and assists in identifying and qualifying alternatives.

Due to similar missions in similarly harsh environments, the Department of Defense (DoD) often works with TEERM on joint efforts. For example, TEERM and the U.S. Air Force Space Command (AFSPC) have worked together on projects to validate protective coatings on launch facilities while reducing the environmental impacts of maintenance. TEERM is working with numerous defense and space contractors on reliability testing of lead-free alloys for electronics soldering.

2009 C3P/NASA Workshop

In November 2009, the Centro Para Prevenção da Poluição (C3P) and NASA hosted a technical workshop on environment and energy at the GE Global Research – Europe facility in Garching, Germany. The workshop provided an excellent forum to showcase innovative and emerging environmental and energy technologies, share lessons learned, and identify new joint opportunities. Individuals from several countries attended, including students and professors from the University of California, San Diego (UCSD), the Technical University of Munich, and the Munich University of Applied Technology. Forty U.S. and international subject matter experts presented on topics ranging from renewable and alternative energies to climate change response to electronics recycling, among others. The week's events included a tour of GE's gas engine manufacturing plant in Jenbach, Austria. Workshop presentations can be found on the TEERM website. C3P and NASA plan to host the 2010 workshop at the UCSD, Jacobs School of Engineering in San Diego, California on November 2-4, 2010.

TEERM also maintains relationships with established DoD working groups, such as the Joint Group on Pollution Prevention. Over the years TEERM has also been involved in projects sponsored by the DoD's Environmental Security and Technology Certification Program.

International partnering provides collaborative opportunities within the global science community to maximize the scientific value of any engineering activity while minimizing costs. It also provides access to information needed for validation under a broad range of conditions and helps NASA engineers stay abreast of international environmental directives that affect NASA and the U.S. in this global market.

In recent years, TEERM and the European Space Agency have been exploring opportunities of mutual concern. Work is progressing to develop joint projects that will help both agencies continue to explore the mysteries of the universe while protecting our home planet.

TEERM also has a partner institution with the C3P. C3P is effectively the TEERM counterpart organization in Portugal. Through joint terms of reference between NASA and Portugal's Institute of Environment, NASA has a formal working relationship with C3P. TEERM staff has provided mentorship and technical and administrative support to C3P for a number of efforts.

The involvement of partners from the outset of a project is essential to transferring knowledge and thus, technology acceptance. Trust and mutual respect between TEERM and their partners is developed as quickly as possible in the relationship and maintained throughout the collaboration. Working together benefits all parties involved as well as the environment.

Materials Management and Substitution Efforts

Coatings for Launch Structures

NASA and U.S. Air Force space launch facilities and support equipment are coated with materials to protect them from the harsh effects of corrosion and thermal ablation.

The most commonly used coatings contain zinc, volatile organic compounds (VOCs), or isocyanates. These materials, however, are subject to increasing environmental and safety regulations and concerns. In order to address these compliance needs, more environmentally friendly coatings are being developed.

TEERM is teaming with the NASA Corrosion Technology Laboratory, the Kennedy Space Center (KSC) Engineering Directorate, AFSPC, Air Force Research Laboratory's Coatings Technology Integration Office, Patrick Air Force Base, Cape Canaveral Air Force Station, and Vandenberg Air Force Base on multiple projects to evaluate new coatings for use at launch support facilities. These efforts are evaluating coatings that can withstand the extreme temperatures and corrosive exhaust gases from rocket launches while providing corrosion protection. All alternatives are being evaluated for environmental impacts.

One technology being evaluated by the Air Force and TEERM is gas dynamic spray technology. Also commonly called cold spray, the technology can be used on a wide variety of substrates with many different materials available. The technology can result in reduced maintenance and hazardous materials/wastes compared to the current processes.

Low VOC Coatings Field Testing

The Low VOC Coatings and Depainting Field Testing project was conducted to field-demonstrate and qualify alternative surface preparation processes and low/no-VOC, non-hazardous coatings for Air Force and NASA launch structure maintenance operations. Two depainting alternatives and six coating alternatives, identified in part from prior NASA studies, were demonstrated at Space Launch Complex 17, Cape Canaveral Air Force Station.

Field observations were made by engineers from the NASA Corrosion Technology Laboratory at KSC. Demonstrated depainting alternatives are recyclable and can reduce waste. The equipment also reduces the amount of particulate matter emitted.

The alternative coatings were applied to two separate areas of the facility. Coatings in the first area were evaluated for corrosion protection over an 18 month period at 6 month intervals. Over that period of time, the coatings showed no degradation of color, gloss, or

corrosion resistance. These are very favorable results considering the proximity of the facility to the ocean.

The second area was directly exposed to indirect exhaust gas and heat impingement during launch. These coatings survived five launches and still provided acceptable protection of the structure. Previous coatings were typically reapplied after every launch resulting in large amounts of waste, high labor costs, and reduced mission readiness.

Non-Chrome Coating Systems

The Non-Chrome Coating Systems for Aircraft and Aerospace Applications project is a coordinated effort by NASA and the U.S. Air Force to test complete coating systems that are free of hexavalent chromium. Stakeholders include personnel from NASA KSC, NASA Marshall Space Flight Center (MSFC), the Air Force Research Laboratory, the University of Dayton Research Institute, Hill Air Force Base, Boeing, and United Space Alliance.

The project is focused on coatings for outer moldlines of NASA and DoD aircraft and space vehicles. Substrates include typical aluminum alloys as well as NASA-specific lithium-aluminum alloys used on legacy and future space flight hardware.

NASA TEERM has completed the first phase (screening testing) and begun the second phase of testing in accordance with a joint test plan that meets the critical performance requirements of all the project team members. Phase 1 testing included Salt Fog, Cyclic Corrosion, Filiform Corrosion, Hydrogen Embrittlement, Adhesion, and Dissimilar Metal Corrosion.

The project builds off prior TEERM efforts that include the NASA/DoD first phase testing of five alternatives and the NASA/C3P project where chrome-free systems were flight tested on an Airbus A-380 commercial aircraft.

Life Cycle Corrosion Testing

Existing test procedures to evaluate coating system's corrosion resistance have disadvantages such as the long time required for validation (18 months) and the fact that the results are not always reflective of real-world performance. TEERM determined a need to establish an accelerated test that more accurately represents coating performance in

service. The ability to determine how a system performs after repair and re-work is also invaluable.

In order to obtain a clear understanding of the lifecycle environment as it pertains to corrosion potential and coating repair cycles, TEERM has initiated testing at KSC Launch Complex 39B to help characterize the environment in order to simulate it in a laboratory setting. Testing will also be performed on the repair and re-exposure to better understand the necessity of maintenance. Information regarding weather and ozone data has also been gathered. Later testing will expose test specimens to other environmental conditions.

Lead-Free Electronics Testing

Major commercial suppliers of electronics have begun moving away from lead-based solders in their standard products. Using a lead-free component could compromise performance as compared to traditionally used tin-lead solder. Previous work indicates that reworked and mixed solder joints have reduced reliability, but data has been insufficient.

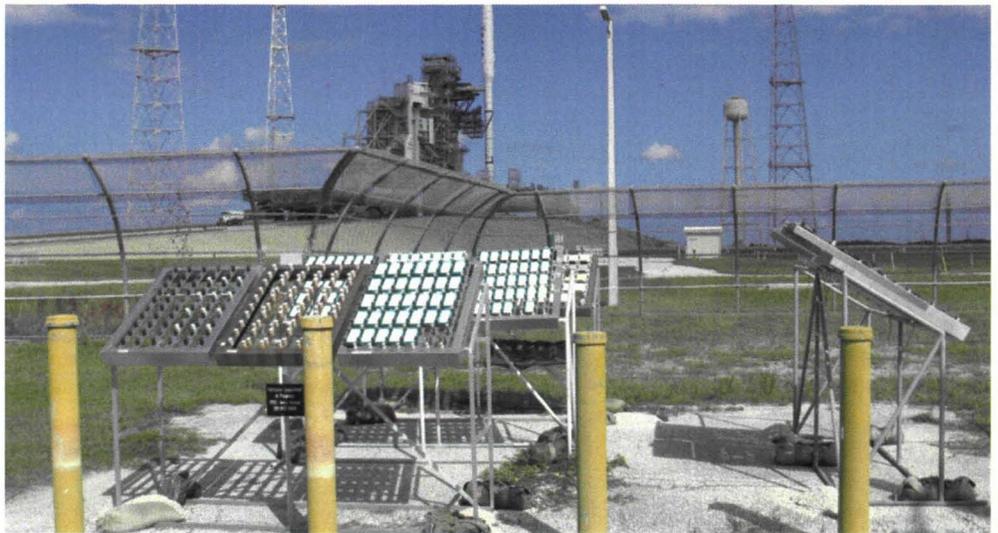
This joint project focuses on the rework of tin-lead and lead-free solder alloys. It includes the mixing of tin-lead and lead-free solder alloys. Data generated from the project will help in better understanding how lead-free electronics will perform in high-reliability applications, thus reducing risks. The project will also be of potential interest to component manufacturers supplying to high reliability markets.

Testing includes Thermal Cycling, Vibration, Combined Environments Testing, Drop Testing, Mechanical Shock, Integrated Stress Testing, and Copper Dissolution. Much of this testing was completed in 2009; failure analysis and project reporting is planned next.

Lead-Free Electronics Demo in Space

While there is little doubt that lead-free electronic parts have flown in space before, they have never been subjected to harsh space environments under controlled conditions where post-flight failure analysis was later performed. To address the reliability concerns of lead-free soldered joints, a need exists to determine the effect of higher reflow temperatures on printed wiring boards and functional integrated circuits and to gather data in an operational environment.

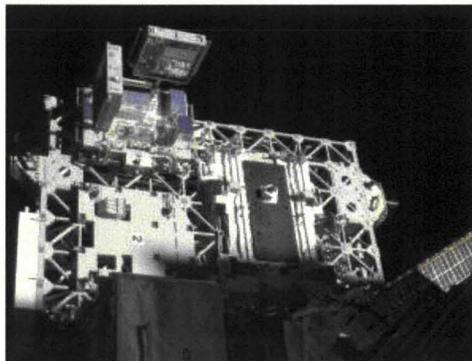
The Lead-Free Technology Experiment in Space Environment (LTESE) experiment, led by MSFC, is a small active package containing test boards and a data acquisition system. It was launched November 16, 2009, on STS 129, and installed on the outside of the International Space Station. The plan is to record the resistance of each circuit and temperature in the box at periodic intervals. The desired time frame for exposure to a space environ-



Life Cycle Corrosion Test Site near Pad 39B with Ares 1-X on-site

ment is for approximately one year.

MSFC has been an active stakeholder in TEERM lead-free electronics projects from the beginning. The LTESE experiment uses components and materials similar to those found on test vehicles used in TEERM lead-free electronics projects. In using similar components and materials, data from LTESE and the TEERM projects can be correlated.



Materials International Space Station Experiment-7 where LTESE is located

Alternative to Nitric Acid Passivation

Nitric acid is the most widely used alternative to passivate stainless steel. Environmental impacts include large amounts of hazardous waste and nitrogen oxide emissions. In addition to the environmental concerns, there are process concerns such as removal of beneficial ions from the surface. Citric acid has been identified as a bio-based alternative.

In 2009 TEERM began actively working with NASA Centers and contractors and DoD partners to investigate the feasibility of using citric acid as a substitute for nitric acid. Approval of citric acid will eliminate use of a hazardous material, a hazardous waste stream, and nitrogen oxide emissions. In addition, citric acid will improve worker safety and possibly corrosion protection because other ions are not removed from the surface.

Corn Based Depainting

TEERM is developing a project to evaluate corn hybrid polymer as an alternative to plastic blast media used to remove coatings and prepare surfaces prior to repainting. Corn hybrid media blasting has performance and environmental benefits over plastic media blasting. Of note is corn hybrid's effectiveness at removing coatings from delicate substrates without causing loss of substrate or other physical damage. From an environmental standpoint, corn hybrid media is made from renewable resources and generates less volume of waste when used at optimal recycle rates. Plans are underway to demonstrate corn hybrid blasting at a NASA Center in 2010.

Pollution Control Efforts

Hypergolic Propellant Destruction Evaluation

At space vehicle launch sites, toxic vapors and hazardous liquid wastes can result from the handling of hypergolic fuels and oxidizers. Current treatment and disposal methods for hypergolic propellants result in large expenses for most NASA and Air Force facilities that handle these materials.

This project is assessing the feasibility of using microwaves to destroy hypergolic propellant waste generated at KSC and Cape Canaveral Air Force Station. It capitalizes on prior work on microwave destruction technology performed by the U.S. Air Force. If proven, the microwave technology stands to reduce the environmental and cost risk posed to current and future space missions.

Berlenga Island

TEERM's partner in Portugal, C3P, is leading a team to reduce the carbon footprint and environmental presence of visitors to Berlenga Island Nature Reserve, a small island

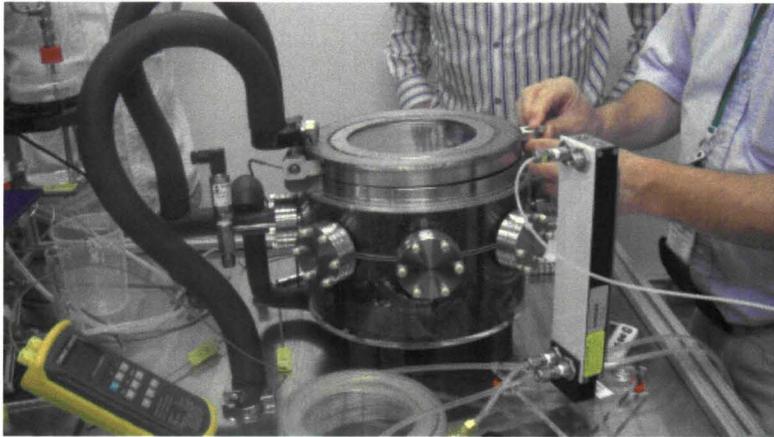
off the coast of Portugal. The focus of the project is to address all community needs (environmental, energy, potable and service water, waste treatment, and transportation) for the island. A variety of renewable energies such as solar panels, wind turbines, and wave energy production technologies are being examined as the best means of meeting energy demands. In addition, the plan will offer solutions for pollution prevention to resource conservation to recycling, incorporating both low-tech and high-tech solutions.

Alternative Energy Efforts

Hydrogen Sensors

Hydrogen is an invaluable alternative for energy sustainability and efficiency. Hydrogen fuel cells operate cleaner, are more efficient, and have better reliability than their petroleum-based counterparts. NASA is evaluating hydrogen fuel cell emergency generators as replacements for existing backup power units.

The development of efficient hydrogen production, storage, and utilization technologies brings with it the need to proactively detect and pinpoint hydrogen leaks for the protection of personnel and equipment. TEERM is in the early stages of a project to evaluate hydrogen sensor technologies to accelerate deployment of stationary fuel cell installations at NASA facilities while mitigating associated safety risks.



*Hydrogen Leak Multi-sensor Test Chamber Developed by
National Renewable Energy Laboratory*

Energy and Water Management

TEERM has been supporting NASA Headquarters Environmental Management Division in creating and refining a NASA-wide energy/water management action plan. The action plan covers all current mandates for federal facilities and discusses ongoing efforts to provide useful feedback from NASA Headquarters to the Centers and component facilities. The concept of the action plan is to give guidance to Center energy/water managers and to provide information on Center requirements for the development of Center-level strategic/action plans.

TEERM engineers have been developing "Center Dashboards" that show at a glance the current scorecards for key metrics, including energy/water intensity, renewable energy usage, and funding needs. Additionally, the dashboards are planned to include fleet vehicles and greenhouse gas metrics when data is made available.

Remediation Efforts

Removal of PCB Contamination

A number of NASA Centers have used Polychlorinated Biphenyl (PCB) containing materials that have subsequently ended up in surrounding sediment systems. Each Center is evaluating remedy technologies that may have application to their environmental problems; however, there are only limited options available for application to sediments containing PCBs. Currently, the most utilized option is dredging followed by disposal in a regulated landfill. The Engineering Directorate at KSC has been working on a two part process that eliminates the need for dredging and instead treats contaminated sediments in place.

TEERM now part of Engineering Directorate at KSC

TEERM is proud to have joined Kennedy Space Center's Engineering Directorate (NE) in 2009. NE, which is led by Mr. Pat Simpkins, provides engineering and science expertise to design, build, sustain, and operate KSC ground support equipment, facilities, ground systems, and flight systems to meet current and future space flight customer needs. TEERM believes that its own mission fits in perfectly with that of the Directorate and looks forward to working with all the excellent people it includes.

TEERM Support

Technical, engineering, business, and management support for TEERM is provided by staff from ITB, Inc., headquartered in Dayton, Ohio. ITB has been part of TEERM since the program's inception in 1998. ITB TEERM engineers identify opportunities for collaboration and develop them into joint projects, which ITB then manages or otherwise supports. ITB also provides support to NASA Headquarters on environmental, energy, and water matters. ITB is also a valuable resource in NASA's partnership with C3P in Portugal.

This is a publication of the
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For more information,
please visit our website at
<http://www.teerm.nasa.gov>

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