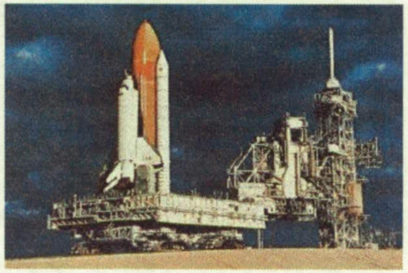
National Aeronautics and Space Administration (NASA)

NASA TEERM Principal Center Overview Mission Risk Mitigation-The Driving Force Behind JG-PP

Technology Programs & Partnerships Branch
Applied Technology Directorate
Kennedy Space Center, FL



CSIMP
18 March 2008
San Diego, CA

Presenter: Charles Griffin, Manager

Agenda

- TEERM Program Mission, Background, and Partners
- Projects

Technology Evaluation for Environmental Risk Mitigation (TEERM)

Mission

To identify and validate environmental technologies through joint activities that enhance mission readiness and reduce risk while minimizing duplication and associated costs.

TEERM Program Background

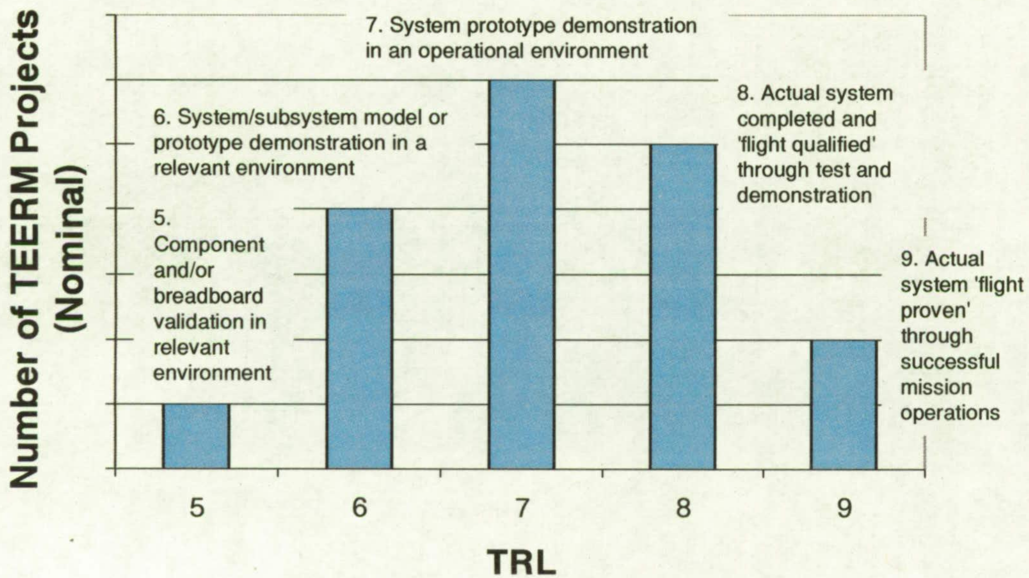
- NASA TEERM has been a valuable resource to NASA in fostering and managing joint testing projects to qualify cost-effective pollution prevention technologies.
- TEERM projects focus on mitigating ***environmentally-driven risk to mission.***
  - Hexavalent chromium → Surface coatings → Costs increasing for compliance with occupational safety and hazardous waste regulations
  - Lead → Electronic soldering and surface finishes → COTS parts now largely lead-free, but lead-free reliability questionable
  - Isocyanates → Components of coatings on launch pads and ground support → Use is banned or restricted by NASA Centers
- By reducing risk to mission, TEERM is also helping NASA reduce risks to the environment.
- TEERM's collaboration with other Agencies and with industry helps improve NASA's ability to adopt new material to reduce unacceptable mission risks in a more proactive and cost effective manner, and to better position itself to respond to new global regulatory and business paradigms.

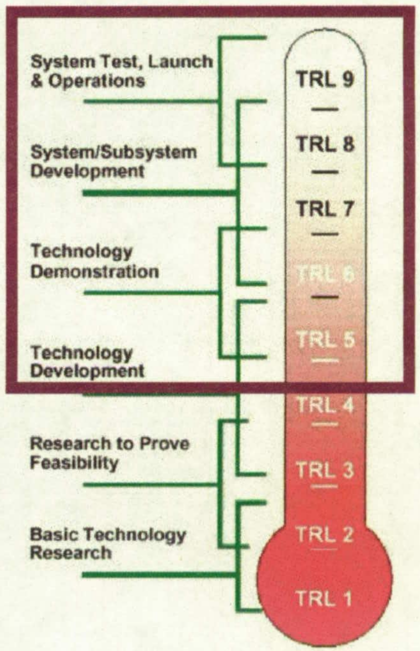
TEERM Program Background

- Role of TEERM in joint projects
  - Project manager where NASA has prime interest
    - Other projects TEERM is team member/ NASA liaison, ensuring that NASA requirements are addressed
  - Source of funding for testing (seed money)
  - Author of joint technical documents
  - Follow through to next logical step (implementation, further testing, or back to R&D).

TEERM Approach to Project Development and Execution

- Stakeholders from two or more NASA Centers/ Programs, or two or more Agencies (e.g., NASA and Air Force).
- Objective to demonstrate/validate new materials or processes to replace hazardous materials to mitigate risks.
  - Aim for work efforts with Technology Readiness <u>Levels 5 thru 9</u>.





TEERM Program Background

- TEERM uses structured approach
  - Seek consensus from technical representatives on all key decisions
    - Scope of project
    - Alternatives to test
    - Testing sites
    - Conclusions of testing
  - Seek contributions from stakeholders, whether direct or in-kind.
    - Often start "seed" money with in-kind contributions. Additional/ 3rd party funding may be sought for testing.
  - Seek early involvement of appropriate engineering authority
    - SSP & Centers; increasingly involving Constellation
  - Support technology implementation process
  - Support evolution of technology
  - Avoid projects with export control issues

Benefits of TEERM Approach

- Sharing of resources reduces the cost to test and qualify alternatives
  - Historical average 3:1 return on NASA investment.
- Enhanced technical confidence in alternatives identified and tested because of direct involvement and structured methodology.
- Avoids duplication of effort among different parties.
- Improve the overall technical quality of the effort through knowledge sharing.
- Accelerates implementation of qualified alternatives.

TEERM Partners within NASA

- ***Shuttle Environmental Assurance (SEA) Initiative***
  - Working on a "Lessons Learned" document regarding hexavalent chrome coatings and cadmium plating for new programs.
- ***KSC Corrosion Laboratory***
  - Testing partner and subject matter expert on many TEERM corrosion/ coatings projects.
- ***NASA Electronics Parts and Packaging (NEPP) at GSFC***
  - Worked together to address lead-free electronics issues.
- ***Developing Partnerships***
  - ***NASA JSC Orion/CEV Materials and Processes (M&P).***
    - ✓ Joining *Orion Finishes Team* to test and evaluate for design the corrosion protection finishes for the entire Orion vehicle.
    - ✓ JSC Power Systems Development: Interest in demonstrating renewable energy technologies for Moon base applications.
  - ***KSC – Florida Power & Light proposal for renewable energy site(s) on KSC property.***

TEERM Partners within DoD

- ***Joint Group on Pollution Prevention***
  - JG-PP Membership (core members from each military service, NASA, and Defense Logistics Agency).
    - ✓ Principal members – Senior Executives Services.
    - ✓ Working Group members – supervisory environmental leads.
  - ❖ ***NASA took over Chairmanship of JG-PP in October 2007.***
- ***JG-PP affiliate partner (developing)***
  - National Association of Environmental Managers (NAEM) Chemical Risk Management Work Group – provides DoD expert involvement, to:
    - ✓ Improve DoD's practices to reduce unacceptable chemical risks
    - ✓ Enhance the testing and acceptance of alternative technologies
    - ✓ Assess changing industry and DoD realities in light of new global requirements

TEERM Partners within DoD

Other DoD partners and their interest areas

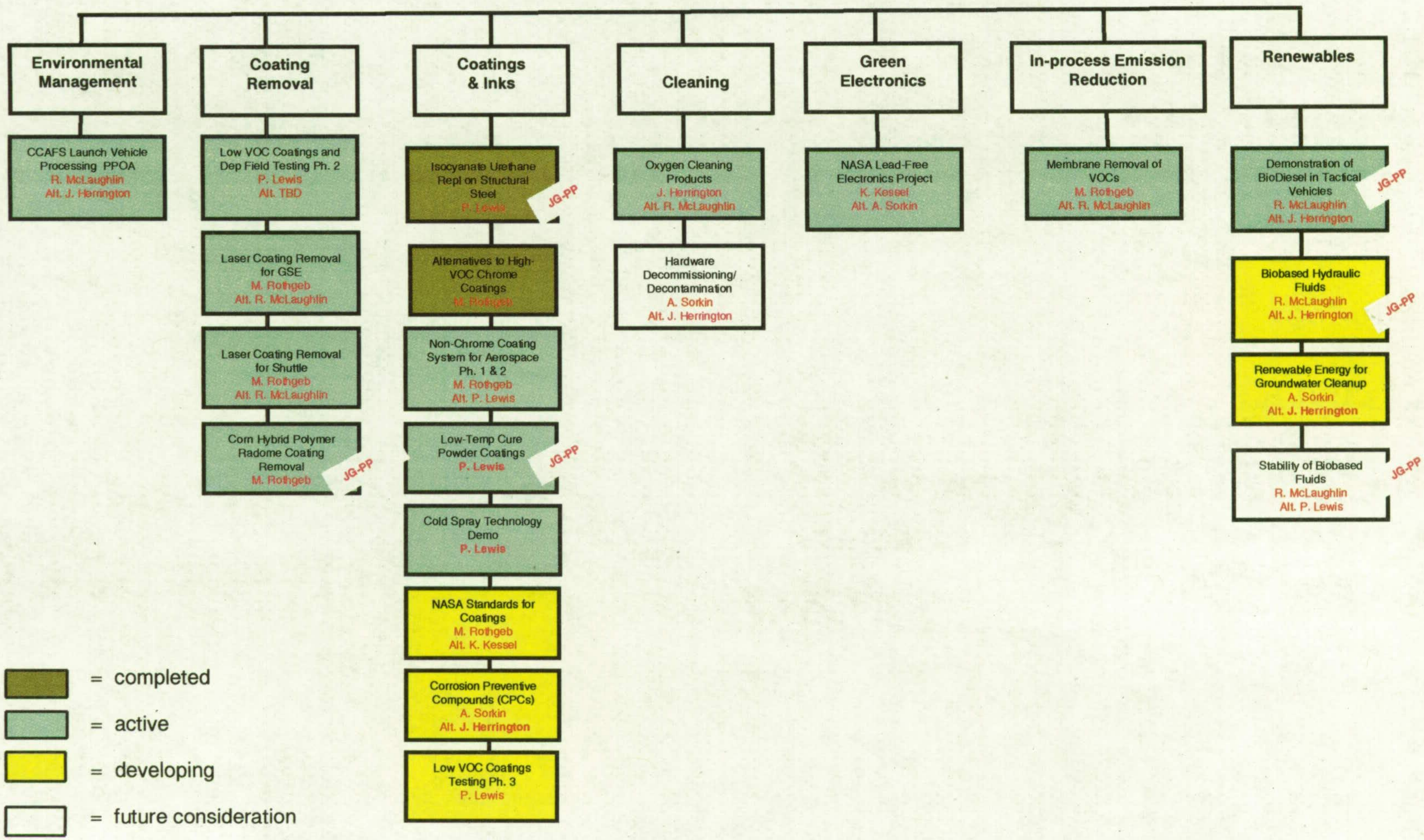
- ***Air Force Space Command***
  - Coatings: volatile organic compounds and hexavalent chrome.
  - Depainting: particulate emissions and hazardous waste.
- ***U.S. Air Force***
  - Coatings: volatile organic compounds and hexavalent chrome
  - Laser coating removal
  - Lead-free electronics
- ***U.S. Navy***
  - Biobased fluids
- ***NAVSEA Crane and Defense Micro-Electronics Activity (DMEA)***
  - Lead-free electronics

TEERM Partners Internationally

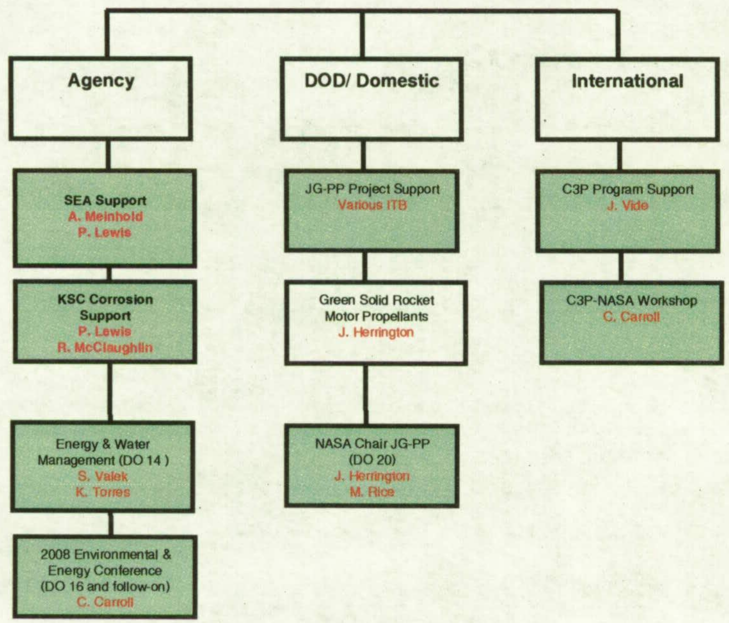
Current Signatories to C3P Protocol	*Interest*
• National Association of Electric and Electronic Manufactures (ANIMEE), Portugal	Lead-free solder
• TAP Air, Portugal	Low-VOC/Non-Chrome Coatings
• OGMA – Aeronautical Industry of Portugal	Low-VOC/Non-Chrome Coatings
• BAE, U.K.	Chrome-free coating systems and Lead-free solders
• Portuguese Air Force	Chrome-free coating systems
• INASMET, Spain	Lead-free solders and testing lab
• SetCom, Portugal	Lead-free solders
• Israel Aircraft Industries	Lead-free solders

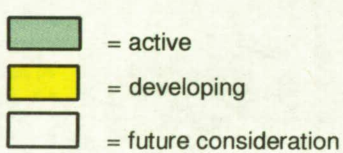
National Aeronautics and Space Administration (NASA)

TEERM Work Breakdown Structure Demonstration/Evaluation Projects



TEERM Work Breakdown Structure
Technical Support Efforts



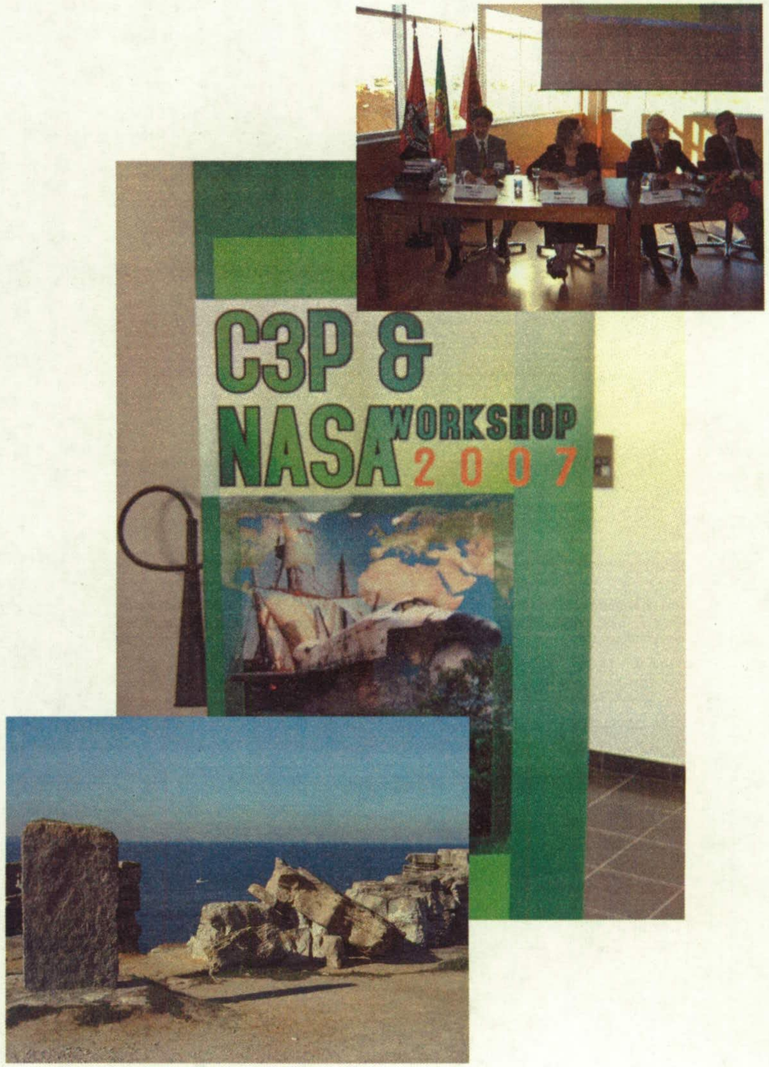


Outreach: Recent & Upcoming Conference Support

☑ ***2007 NASA-C3P P2 Workshop:*** November 7-9, 2007, Peniche, Portugal

- ***2008 NASA Biennial Environmental and Energy Conference:*** TBD (likely Sep. 2008, Orlando, FL)
- ***2008 NASA-C3P P2 Workshop:*** November 18-20, 2008, San Diego, CA

TEERM support includes developing program, inviting speakers, giving presentations, and moderating sessions.



Lessons Learned from Shuttle Experience

– **Communication among Elements is very important**
  - Environmentally-driven risks affecting one Element can also affect other Elements
  - One Element may find a solution that is applicable to others thus saving time and effort

– **The earlier the collaboration among Elements on common issues, the more beneficial the outcome**

– **Collaboration results in less duplication of effort and cost for the program/Agency as a whole**

– **Proactively working with regulatory agencies is essential for allowing the continued use of restricted materials necessary to programs**

Summary

– **TEERM desires that Constellation needs be incorporated in active and future TEERM projects**

– **Early technical exchange ensures more opportunities to work together on issues of mutual interest**

- Ensure that information is not lost in the transition from Shuttle support to Constellation
- New projects are currently being developed, and it would be advantageous to include Constellation requirements now

Backup Slides

Projects
(active and developing)

TRL
7

Non-Chrome Coating Systems for Aerospace Applications (NASA-DoD)

Description:

- Evaluation and testing of non-chromated coating systems as replacements for hexavalent chrome coatings in aircraft and aerospace applications.
- Recently added: evaluation of non-chrome coatings for electronic housings as a focus area of Phase II.

Benefits:

- Meet EPA and OSHA requirements
- Reduce maintenance cost and government liability associated with continued use of chrome-containing coatings
- Addresses NASA and Air Force requirements on AL alloys 2219, 2195, 6061, 2024 Bare, 2024 Clad, and 7075.

Stakeholders:

- NASA (KSC, MSFC M&P, Boeing, Hill AFB, United Space Alliance, SEA) (Constellation has shown interest)
- Air Force (Hill AFB, WPAFB AFRL & MLBT)

Achievements:

- Completed 1,000 hour Filiform testing (KSC)
- Completed 2,000 hour salt-spray testing (Hill AFB)
- Completed 2,000 Cyclic Corrosion testing (MSFC)
- Completed Dissimilar Metals Corrosion testing (Boeing)
- Completed Dissimilar Metals - Simulated Aircraft Structures Corrosion testing (Wright-Patterson AFB)
- Completed Hydrogen Embrittlement testing on magnesium-rich coatings (Hill AFB)
- Completed Adhesion testing (Hill AFB)
- Began drafting Joint Test Report (October 2007)

Future Plans:

- Complete Test Report for Phase I testing (1Q 2008)
- Complete PAR and JTP for Phase II (1Q 2008)
- Begin testing for Phase II (1Q 2008)

TRL

3

Corrosion Preventive Compounds (CPC)

Description:

- Solid Rocket Motor Propellant Issue:

-Many materials that would otherwise resist corrosion fail in the KSC environment due to the acidic exhaust from solid rocket boosters. These materials can be costly to replace or maintain, and pose environmental (esp. VOC) concerns. Cryogenic flex hoses are routinely removed from the pad for maintenance. Corrosion Preventive Compounds (CPCs) are used by NASA, DOD, AFSC, and others. Testing is needed to evaluate the performance of CPCs under KSC launch pad conditions.

- Most CPC's are high VOC content which put them at risk for obsolescence. CPCs are inexpensive and easy to apply.

Stakeholders:

- TBD (can include NASA Launch Services Program, VA-A, Constellation Program, AFSPC, Shuttle Program)

Benefits

- CPCs provide a relatively low cost and low maintenance method for preventing corrosion on existing structures.
- Reduces mission schedule risk by increase lifetime of launch pads and GSE and reducing replacement and maintenance cost.
- Reduce Risk of Obsolescence on Shuttle Pad flex lines due to production halt of AR7
- Area of keen interest by AFSPC, JCAA and Services; leveraging likely from DoD

Applications

- Launch pads and GSE
- All structures exposed to Solid Rocket Propellants:
  - AFSPC shares mutual interest due to planned continued use of solid rocket booster propellants

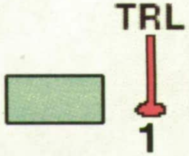
Accomplishments

- Identified potential alternatives
- Confirmed potential Ares interest

RLM1

Slide 20

RLM15 This section is inconsistent with other slides.
Rusty McLaughlin, 12/20/2007



Oxygen Cleaning Products

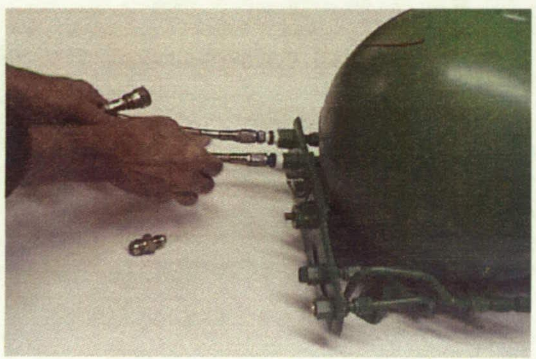
Objective:

- The primary objective of this project is to challenge academia to evaluate and potentially formulate a new oxygen cleaner through green chemistry. Potential alternatives will then be phased into Dem/Val project to validate possibilities. Results will compile a Guidance Document that will assist NASA in determining areas of risk associated with Class II ODC's in Oxygen Line/Systems Cleaning.

Current best-available products for cleaning space oxygen systems are Class II ODC's, which must be phased out by 2015.

Stakeholders:

- NASA and Yale Univ.



Benefits:

- Summarize Class II ODC issues and compare/ contrast previous and future cleaning product development and test programs.
- Use Guidance Document to guide policy development, to develop Agency strategy, and to inform programs of potential Class II ODC impacts.
- Greatly reduce risk associated with current Class II ODC cleaning products.

Achievements:

- Communication initiated with WSTF and product mfrs, 3M, Asahi Glass, Micro Care, USAF/NATO, EPA, etc.
- Initiate green chemistry study at Yale University in Fall 2007 (contract finalization)

Future Plans:

- Track laboratory progress and assist as necessary.
- Inform NASA of future non-ODC cleaning product opportunities and identify areas where non-ODC cleaning product implementation could be possible.
- Identify risks to NASA of different non-ODC cleaning scenarios (both switching to non-ODCs as well as staying with Class II ODCs).

TRL

5

NASA-DoD Lead-Free Electronics Project

A focus on the rework of tin-lead and lead-free solder alloys and will include the mixing of tin-lead / lead-free & lead-free / tin-lead solder alloys during manufacturing and rework

Description:

Joint DoD-NASA-OEM project will build on the results from the JCAA/JGPP LFS Project.

Consumer electronics are driving the commercial market to lead-free alternatives causing a situation where aerospace OEMs and agencies must deal with the introduction of lead-free in to high reliably electronics.

The primary technical objective of the project is to undertake comprehensive testing to generate information on failure modes/criteria to better understand the reliability of solder interconnects assembled and reworked with lead-free alloys and with mixed (lead/lead-free) alloys.

Benefits:

Project will fast-track since we are building off of the JCAA/JGPP LFS Project

Data generated from the this project is required to gain a better understanding of how lead-free electronics will perform in high-reliability aerospace applications.

Accomplishments:

Secured project funding for test vehicle assembly and harsh environment testing

Joint Test Report Finalized October 8, 2007, posted to web shortly thereafter

Overview Presentation Given at Diminishing Manufacturing Sources and Material Shortages (DMSMS) Conference – November 1

Test Vehicle Assembly Winter 2008

Sub-contracts in place with testing facilities

Future Plans:

Finalize Project Plan – 1Q 2008

Begin Rework Efforts – 1Q 2008

Joint Service Lead-Free TCM – 1Q 2008

Begin testing – 2Q 2008

CSIMP Conference – 2Q 2008

RLM16

Slide 22

RLM16 Should remove "of" for consistency?
Rusty McLaughlin, 12/20/2007

Potential TEERM Interest Areas for Constellation

Need	Risk	Prior Projects	Outcomes	Potential New Projects
Coating: Replacement for hexavalent chromium used in conversion coatings and primers for corrosion protection	Flight: ESOH risk from continued use, schedule and cost risk from material obsolescence	• JG-PP Non-Cr Primer	Flown on Orbiter; qualified for some applications	• Testing of Non-chrome Systems **(3)** -- Leverage Phase II Testing • Dissimilar Metals Testing & Analysis of Coatings **(2)**
		• Non-Chromate Coating System for Aerospace	Phase II: Testing Ongoing	
Coating: Replacement for PCE used in ablative coating of External Tank	Flight: ESOH risk from continued use	• Convergent Spray Technology Evaluation	Approved for some cork ablator applications of SRB	• Convergent Spray Technology **(4)** -- Qual Ares I & V
Coating Removal: Replacement of coating removal technologies from small areas of steel surfaces and launch pads	GSE: ESOH and schedule risk of conventional methods	• Portable Laser Coating Removal System	Proven feasible in 2006 demonstration at KSC	• PLCRS II --Nd:Yag
Green Electronics: Replacement of tin-lead soldered/plated parts with lead-free	Flight: Potential obsolescence of lead-plated parts or accidental intrusion of LF parts into Pb flow	• LFS Project 1 • NASA-DoD Lead-Free Electronics Project	Data-ready math modeling; Long term performance of LFS Reliability testing ongoing	• Determination of Solder Joint Species **(1)** -- Evaluation of XRF vs. Laser Induced Breakdown Spectroscopy (LIBS)
Coating: Corrosion Protection of Structural Steel	Flight: Obsolescence risk due to increasing environmental regulation	• Isocyanate Urethane Replacements on Structural Steel • Low VOC Coatings and Depainting Technologies Field Testing Phase 2 • Low/No-VOC and Nonchromate Coating System for Support Equipment	Candidates validated for use as applicable	• Low VOC Coatings for Protection of Structural Steel **(7)** -- Partner with Air Force Space Command

National Aeronautics and Space Administration (NASA)

Potential Interest Areas for Constellation

Need	Risk	Prior Projects	Outcomes	Potential New Projects
Coating Removal: Alternatives for removal of coatings from delicate substrates	Flight: ESOH risk due to use of hazardous chemical strippers, Cost and Schedule risk due to damage of delicate hardware	• Corn Hybrid Polymer Coating Removal	Tested but not validated by Orbiter	• Coating Removal from Delicate Substrates **(9)** -- PLCRS
Coating: Surface Preparation and Corrosion Protection	Flight: ESOH risk due to use of chemical strippers Cost and schedule risk due to increased maintenance cycles	• Parts Washers	Developed a Consumer Guide for alternative cleaners, degreasers, and parts washing systems	• Fluorescent Coating Systems for Corrosion Protection **(8)** • Chemical Rinse Agents for Improved Corrosion Protection and Reduced Maintenance **(11)**
Green Electronics: Replacement of tin-lead soldered/plated parts with lead-free	Flight: Potential obsolescence of lead-plated parts or accidental intrusion of LF parts into Pb flow	• LFS Project 1	Data ready math modeling; Long term performance of LFS	• Determination of Solder Joint Species -- Evaluation of XRF vs. Laser Induced Breakdown Spectroscopy (LIBS)
Other: Next Generation Oxygen System Cleaning Products	Flight: Obsolescence risk of Class II ODCs	• Oxygen Cleaning Systems	Validation of Class II ODCs substitutes for Class I ODCs	• Oxygen Cleaning Products **(5)** -- Green Chemistry
Other: Hardware Decontamination	Health: ESOH, cost risk from hazardous waste disposal	N/A	N/A	• Hydrazine Neutralization **(6)**
Other: Non-Destructive Inspection techniques	Flight: Cost risk	N/A	N/A	• NDI for Corrosion/Damage **(10)**
Other: Replacement of HCFC 141b as blowing agent in foam	Flight: Obsolescence risk of Class II ODCs	N/A	N/A	• Foam Application alternatives
Other: TCA	Flight: Obsolescence risk of Class II ODCs	N/A	N/A	

Potential Interest Areas for Constellation

1) Determination of Solder Joint Species:
With the commercial industry continuing to move towards lead-free electronics and the ever increasing risk that lead-free will unknowingly be introduced into aerospace electronics, there is a need for accurate analysis of solder alloy composition on electronic components and in solder interconnects. The main technology being used for the evaluation of solder alloy composition on electronic components and in solder interconnects is X-Ray Fluorescence (XRF). XRF has some limitations concerning source selection, results analysis and accuracy. Several companies are developing XRF units specifically for the evaluation of solder alloy composition on electronic components and in solder interconnects. Other technologies are also emerging that could be used for solder alloy composition on electronic components and in solder interconnects. One example is laser-induced breakdown spectroscopy (LIBS). The use of LIBS would be a new application of an already proven technology. NASA should take an active role in evaluating current detection equipment and provide critical input so these screening devices can be optimized for use in aerospace applications.

2) Dissimilar Metals Testing & Analysis of Coatings:
There has been interest expressed from MSFC in better understanding coating system performance when applied between dissimilar metals. This project would involve advanced corrosion testing at various distances from the beach to align with launch structures and buildings associated with Constellation. The results should provide insight into corrosion rates of various substrates, more accurate predictions of coating performance, and comparison to current baselines at different locations.

Potential Interest Areas for Constellation

3) Testing of Non-Chrome Systems:
Coatings identified from Phase II of TEERM project should be tested to all NASA specifications, with the ultimate goal of implementation of one or more non-chrome systems across all NASA aerospace equipment. Several applications would benefit.

4) Convergent Spray Technology:
Ares I upper stage was recently awarded to Boeing and their partners (which includes USA – developer of CST). Technology is already approved for application of cork ablator to portions of the SRB system. Lockheed Martin uses similar cork ablator on External Tank, but must large amounts of solvents in application. Adoption of CST in the development process of Ares I and V vehicles could present a large cost savings to NASA. Testing and facility costs associated with implementing a non-CST system and then moving to the CST system at a later date would be avoided.

5) Oxygen Cleaning Products:
Current cleaning processes of oxygen systems use Class II ODCs such as HCFC-141b and HCFC-225g. This project seeks to engage the green chemistry design capabilities at a university to essentially "design out" hazardous constituents. Successful green design could replace hazardous cleaning solvents utilized in production and maintenance of oxygen hardware. Replacement chemicals would mitigate environmental risks associated with development of the Constellation Programs crew breathing and LOX systems.

Potential Interest Areas for Constellation

6) Hardware Decontamination:

Components utilized in hydrazine systems remain contaminated. They must be handled and disposed of as hazardous waste once decommissioned. A chemical substance has been identified that can destroy hydrazine molecules and is being investigated for use in decontaminating hardware and systems. The project seeks application verification to neutralize residual hydrazine molecules that remain in systems hardware, and render the waste stream harmless through chemical reaction. The goal is to dispose of the resultant in routine waste water treatment plants. Successful demonstration/validation can mitigate personnel and environmental risks associated with exposure from contaminated hydrazine systems and hardware. Significant cost reductions may be realized on hazardous waste disposal reducing operational and support costs to the Constellation Program and any other program utilizing hydrazine.

7) Low Volatile Organic Compound (VOC) Coatings for Protection of Structural Steel:

Air Force Space Command and NASA have similar missions, facilities, and structures that are located or operate in harsh environments. Regardless of the corrosive affectivity of the environment, all metals require periodic maintenance activity to guard against the insidious effects of corrosion and ensure that structures meet or exceed design or performance life. Increasing environmental regulations are rendering existing coatings obsolete. New coatings are being developed to meet these more stringent requirements, but need to be tested to determine their acceptability of performance.

Potential Interest Areas for Constellation

8) Fluorescent Coating Systems for Corrosion Protection:

Confirming that a coating has been applied correctly can require an extensive and lengthy inspection process. The use of a fluorescent primer permits faster identification of holidays and areas with low film thickness. Luminescent coatings were originally developed for use in ballast tanks in large ocean-going vessels by the US Navy. Improved coating application will result in less corrosion and required maintenance leading to improved mission readiness with reduced labor and costs.

9) Coating Removal from Delicate Substrates:

Thin aluminum and composite materials are used throughout NASA and the DoD. Conventional abrasive blasting methods can cause damage or warping. Chemical strippers have numerous safety and environmental concerns associated with their use and often require long periods of time to work properly. A coating removal method that is safe to use on delicate substrates could increase efficiency and decrease hazards, while improving mission readiness.

10) Non-Destructive Inspection for Corrosion/Damage:

NDI is the examination of an object or material with technology that does not destroy or damage the product or material. Ultrasonic, radiographic, thermographic, electromagnetic, and optic methods are employed to probe interior microstructure and characterize subsurface features. NDI can result in less required maintenance leading to improved mission readiness with reduced labor and costs.

11) Chemical Rinse Agents for Improved Corrosion Protection and Reduced Maintenance:

Multiple NASA Centers are located near coastal areas. Structures and equipment in these environments are exposed to salt air and salt fog. This constant exposure can result in the build up of salt films that promote corrosion. A chemical rinse agent used at regular intervals could remove those films preventing corrosion and extending the life of the existing coating. Lower amounts of hazardous materials would be used, emissions from depainting and recoating operations would be reduced, and mission readiness would be improved.