



F-35 Pollution Prevention Activities

**ESTCP/SERDP Surface Finishing and Repair Workshop
26 February 2008
Tempe, Arizona**

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Report Documentation Page

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Agenda



- ***What is F-35***
- ***Pollution Prevention (P2) Background***
- ***P2 Implemented System Solutions***
- ***P2 Solutions in Work***
- ***P2 Solutions Offering More Opportunities for Near Term F-35/ESTCP Partnerships***



What is Joint Strike Fighter ?



F-35A



**Conventional
Take Off Landing
(USAF)**

F-35B



**Short Take Off
Vertical Landing
(USMC and UK)**

F-35C



**Carrier Variant
(USN)**





F-35 ESH Requirements



- **Contract Data Deliverable List CDRL-001
Air System Lifecycle Plan**
 - ***Hazardous Materials Reduction/Elimination Initiatives***
 - Identified and Controlled in Detailed Plan 2YZA00049
Hazardous Materials Management Plan
 - ***Demilitarization/Disposal Plans***
 - Demilitarization/Disposal Plan 2YZA00102
- **Contract Statement of Work Commits
LMAero/NGC/BAES to a Hazardous
Materials Management Plan and Formal
Working Group**



The Continuing Sustainability Challenge and Interaction with Design for Environment (DfE)



- **LMAero Solved the Easy-To-Do Material/Process Substitutions on Previous Programs**
 - *Low Hanging Fruit*
 - *Typically Focused on Employee Exposure During Manufacturing*
- **Now the Challenge is to Find Material Substitutions That Reduce Life-Cycle Expense, i.e. Sustainability**
 - *Focus on Customer Maintainers Exposure During Operation, Maintenance, Depot Overhaul, Deactivation, Demilitarization, Disposal*
 - *Awareness of Hazmat Liability to Sub-tier Suppliers due to Current and Future Regulations*
 - *Reduce Life Cycle Cost Impact through Hazmat Minimization*
 - *This Results in the Design for Environment (DfE) Approach*

Identify the Goal and Force the Solution

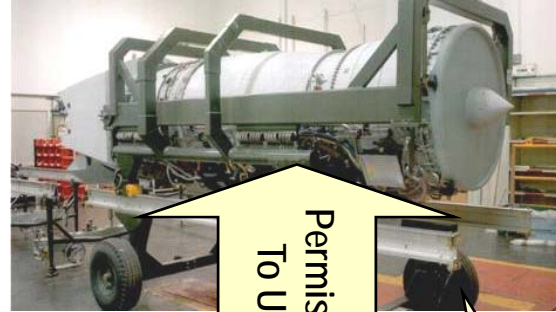
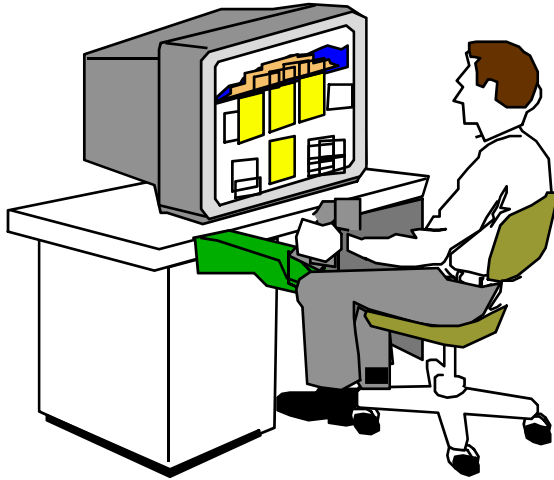


Hazardous Materials Control Approach – Controlled by HMMP and M&P

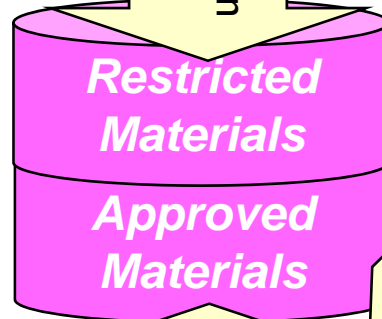


Support Equipment Design

Airframe/
Subcontractor
Design



Permission
To Use



Permission
To Use

Emission Impacts
New Limitations

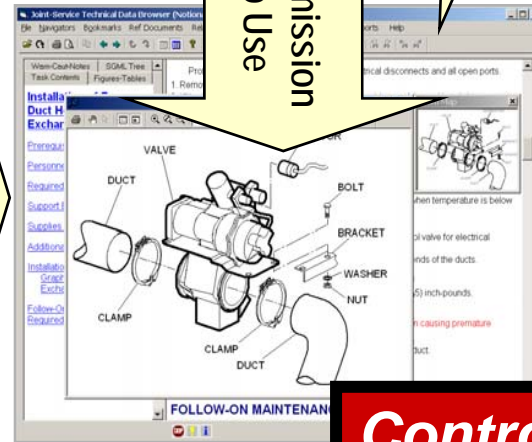
NEPA/Conformity
Planning



Adopt New
Requirements

Tech Data

Permission
To Use



Controlled by
Tech Data



Partner Country
Regulation Research



Supply

Control Materials on Program



System Solutions



System Changes and Improvements Implemented on F-35 With Demonstrable Pollution Prevention Benefits



Key DfE Technology – No Cadmium Fasteners



- **Traditional Aircraft Use Thousands of Steel Fasteners with Cadmium Plating**
 - *Cadmium provides corrosion protection and lubricity*
 - *Exposes Maintenance Workers to Cadmium During Depainting Because They Grind the Old Coatings Off*
 - *Several Thousand Dollars per Year for PPE and Longer Grinding Time Due to Occupational Limits*
- **JSF Uses Titanium or Stainless Steel Fasteners**
 - *No Cadmium*
 - Except for Three Locations with no Drop-in Replacement (QAD, SFD, Gun)
 - *More Expensive Up-front But Less Life Cycle Cost*



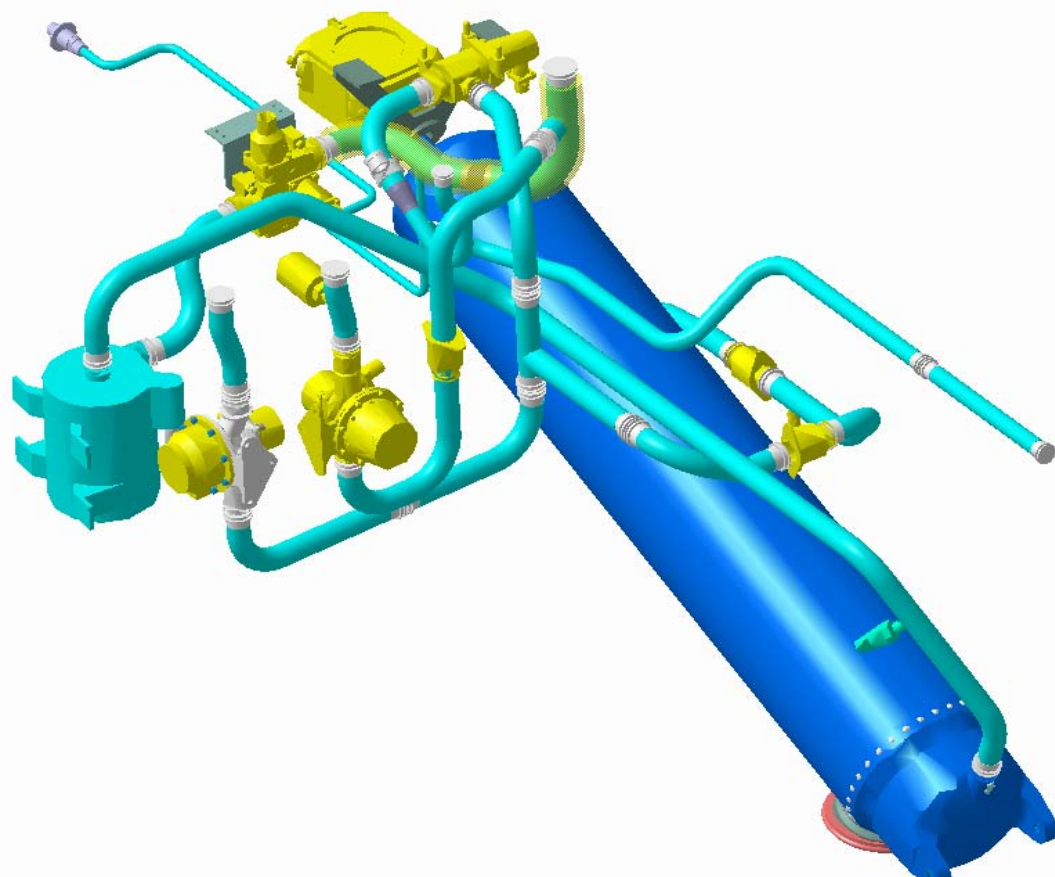
Reduces Up/Down Stream ESH Impact



Key DfE Technology - OBIGGS



- **Traditional Military Aircraft Used Halon 1301 (ODC) to Provide Fire Protection to Fuel Tanks**
 - **Empty Fuel Tank Volume Must be Filled with Inert Gas to Prevent Fire/Explosion from Bullets/Shrapnel**
- **On-Board Inert Gas Generating System (OBIGGS) Replaced Halon 1301**
 - **Filters out Oxygen from Ambient Air to Create Nitrogen Enriched Air Suitable for Fuel Tanks**
 - **Military No Longer Required to Maintain Halon Stockpile for Wartime Fuel Tank Inerting**



No More Halon Stockpiles



Key DfE Technology - OBOGS

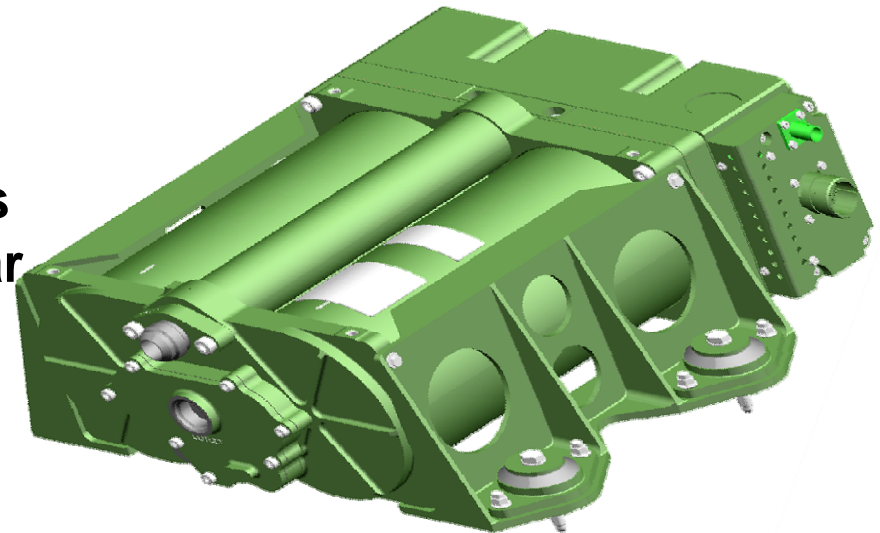


- ***Traditional Aircraft Carried the Pilots Oxygen Supply in Liquid Oxygen Tanks***

- ***Liquid Oxygen will Trigger Rapid Combustion of Any Dirt or Contaminates in the Supply System***
- ***Supply System Must Be Perfectly Clean***
- ***Best Cleaning Solutions Freon CFC-113 and HCFC-141b***

- ***On-Board Oxygen Generating System Replaced Liquid Oxygen***

- ***Produces Oxygen-Rich Breathing Gas From Engine Bleed Air Using Molecular Sieve Technology***
- ***No Exotic Cleaning Solutions***
- ***Military No Longer Required to Stockpile Freon for Oxygen System Cleaning***



No More Freon Stockpiles

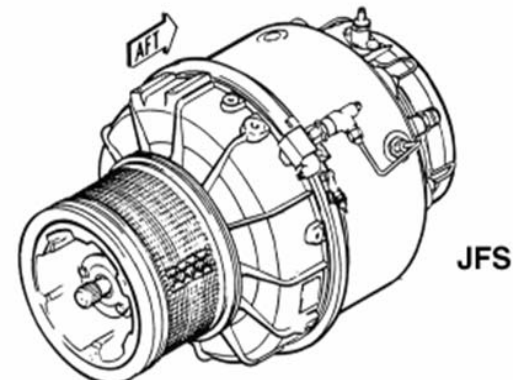


Key DfE Technology - IPP



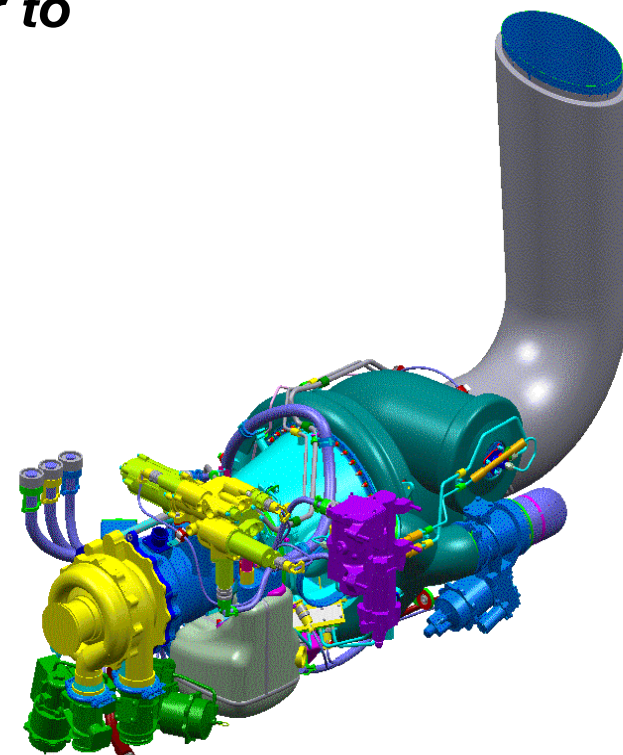
- **Traditional Military Aircraft Contain An Emergency Power Generation System to Restart Failed Engine at Altitude**

- **Some Systems Like F-16s Used Hydrazine**
- **Unstable, Toxic, Dangerous Fluid Produces Gas to Turn a Turbine and Generate Enough Power to Restart Engine**



- **Integrated Power Package (IPP) Replaces Hydrazine System**

- **Small Turbine Engine Integrated with Other Vehicle Cooling/Heating Systems**
- **Basically a Small Jet Engine**
- **Easy to Start/Stop, No Hydrazine, No Leaks**



No More Hydrazine Hazards



Key DfE Technology - HVOF



- **Traditional Aircraft Landing Gear and Other High Wear Surfaces were Chrome Plated**

- **Chrome Plating Bath Environmental Liability**

- **High Life Cycle Cost:**

- **Requires Stripping/Replating every 3-5 Years**

- **Military Services Must Have Plating Facilities**

- **Replating Takes 2-3 Months**

- **Requires Large Quantities of Spares**

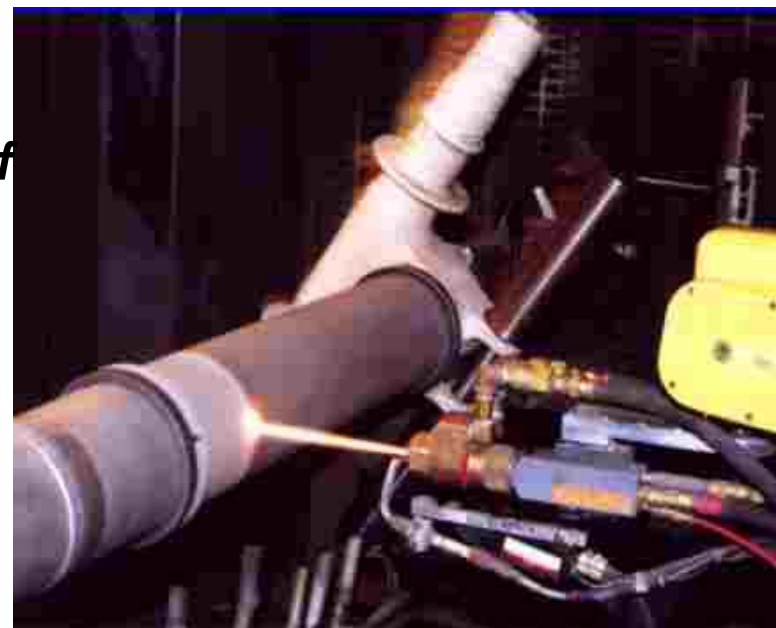
- **High Velocity Oxygenated Fuel (HVOF) Technology**

- **High Velocity High Temperature Stream of Powder Shot Onto Part Surface Forming Hard Impervious Wear-Resistant Coating**

- **Long Life – Minimal Maintenance**

- **Ultra-Smooth Superfinish Extends Life From Seals That Rub Against HVOF Coating**

- **Standard Coating for All JSF Actuators, Wear Surfaces, Landing Gear**



No More Chrome Plating



Key DfE Technology – ODC Free Manufacturing



- ***Traditional Aircraft Fabrication Aids, Sealants, and Cleaning Solutions Often ODC-Based***
 - ***Good Cleanliness and Efficient Product Delivery***

- ***LM Replaced All ODC-Containing Products in 1995***
- ***No Class I/II ODCs Allowed on F-35 to Date***



No More Ozone Depletion



Key DfE Technology Non-Chrome Primer



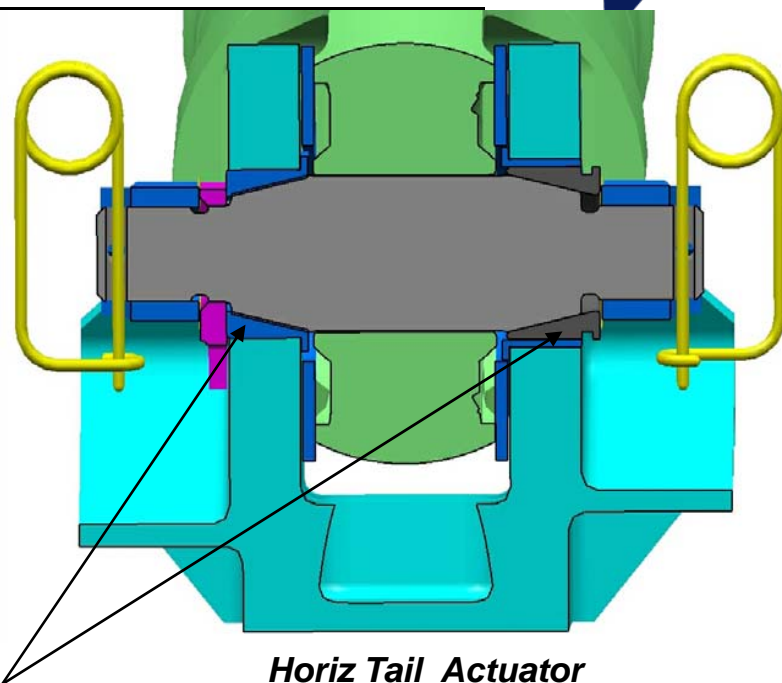
- **Approved Deft 44GN098 as F-35 Structural Primer**
 - *BF-1 Effectivity (First STOVL)*
 - *Fully Implemented on Airframe by BF-4*
 - Implementation on System Suppliers Voluntary to Avoid Costs
- **LM Aero and Northrop Grumman Performed Four Batch Verification**
- **Additional Compatibility with Exterior Finishes and Materials**
- **Qualified to LMA-MR003 Primer Specification**
 - *Equivalent to Mil-PRF-85582*
- **NAVAIR Completed Qualification to Mil-PRF-85582**



Key DfE Technology - Copper-Beryllium Bushing Replacement



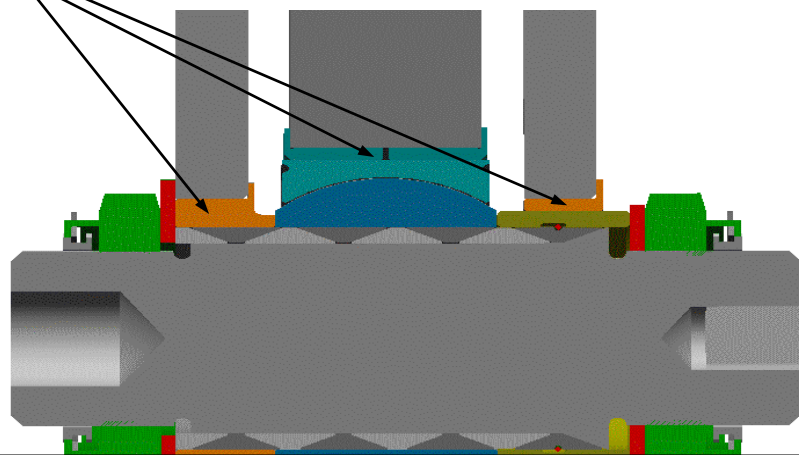
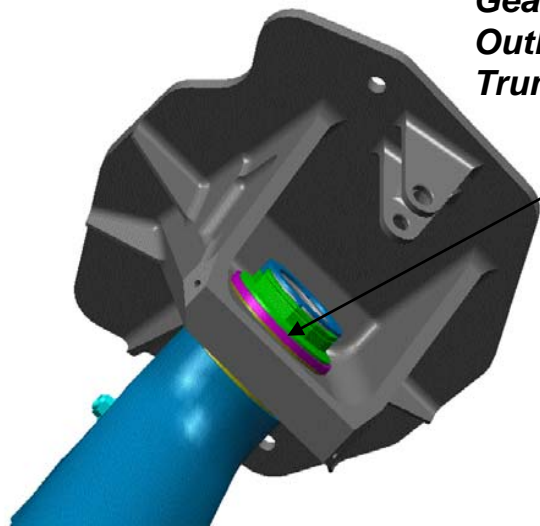
- Copper-Beryllium (Cu-Be) Bushings Added to LMAero Restricted Materials List February 2004
 - *F-35 Technical Mgmt Concurred with Action Plan to Identify Locations and Develop Alternative Material Where Feasible*
- Typically Used for Flight Control Actuators and Other High Load Environments
 - *350+ Specific Locations*
 - *Switched to Other Materials for Many Applications*



Horiz Tail Actuator

Cu-Be Bush

Main Landing Gear OutBoard Trunnion Fitting



Horiz Tail Inboard Hinge

Rapidly Qualify/Implement New Materials



Bushing Replacement Lab Testing



- **F-35 Evaluation of Alternative Materials**
 - *ToughMet, Nitronic 50/60, 304/HBN, SBIR Developed, etc..*
 - *Phase 1 Completed Tensile, Compression, Bearing, and Shear*
 - *Phase 2 Completed Wear and Galling*
 - *Phase 3 Completed Elevated Temp Tensile*
 - *Phase 4 Completed SCC and Salt Fog exposure*
 - *All F-35 Bushings <2.5"Ø Switched to Cold Worked Nitronic 60*
 - *Phase 5 test plan Evaluating Installation Issues*
- **ASC PP3010 FY05-06 Funding**
 - *Subscale Testing and Implementation*
- **Materials Affordability Initiative (MAI)**
 - *25/75 Contractor/Government Cost Share with LM/Boeing/BrushWellman*
 - *Phase III Advanced Screening and Toughmet "S" Basis Generation*
 - *Phase IV Toughmet "A/B" Basis Generation, Fatigue and Fracture, Installation*
 - *Phase V Implementation Studies*

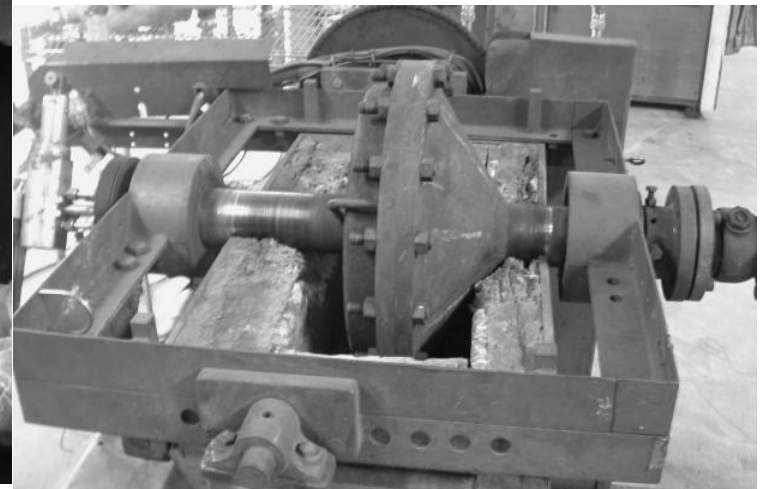
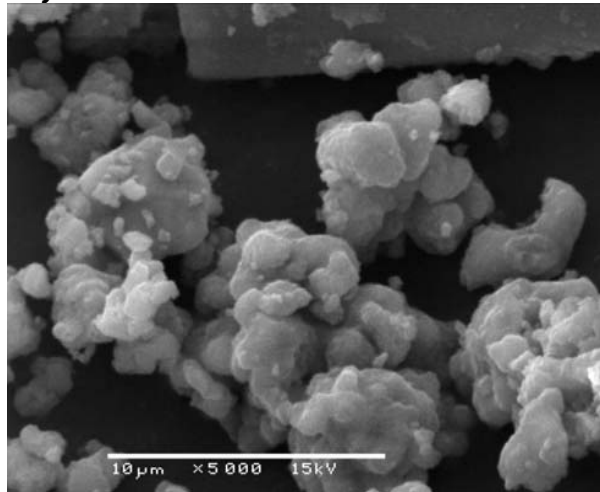




Key DfE Technology - Material Disposal



- **CDRL A001 Requires Disposal Plan**
- **No Available Methods for Composites/Low Observable Materials**
- **Need Recycling Alternative with Beneficial Reuse to Avoid RCRA HazWaste Designation for Disposal**
- **Phase II Air Force SBIR LO Coating Destruction**
 - Phase I Fluidized Bed Reactor Concept Demonstrated Complete Breakdown of Materials and Conversion to Calcium Carbonate
- **F-35 Participating in Phase II**
 - *Provide Materials, Lab Verification of Destruction*
- **ESTCP Scale Up Assistance?**



Eliminate Composite Disposal Uncertainty



Key DfE Technology - Corrosion Detection



- **F-35 Needs Low Budget Device to Solve Several Issues**
 - *Corrosion Detection, Locate OML Panel Edges and Fasteners, Detect Fluid Leaks, Inspect Composite Material Beneath Several Coating Layers, Verify Coating Thickness*
- **Existing Phase II SBIR Developed Microwave Corrosion Detection Device**
- **F-35 JPO ESH Sponsored Phase II Extension and Phase III Commercialization**
 - *LMAero F-35 Generating Reqmts*
- **P2 Benefit – Reduce Scheduled (non-necessary strip/repaint cycles) Coating Maintenance, Minimize Coating Damage During Event Maintenance**



Avoid ESH Impact of Needless Coating Rework



Future ESTCP Cooperation



How F-35 and ESTCP Can Continue to Work Together and Expand Work to Enhance Value



Key DfE Technology - Cadmium Plating



- ***Traditional Aircraft Steel Parts Protected From Corrosion by Cadmium Plating***

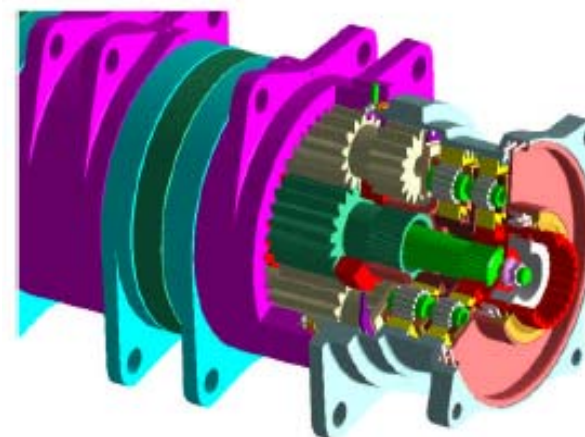
- ***Alternative Technologies Under Development***

- ***ESTCP Funded S-53 High Strength Stainless Steel Dem/Val Program on F-35 RGAs***

- ***Risk Reduction Phase Underway by Fabricating One RGA 'Set' and Fatigue Testing***

- ***LMAero/BAES Studying Corrosion Performance Enhancements***

- ***Full Demonstration Starts 2007***



Rotary Gear Actuators

Eliminate Cadmium Plating



Key DfE Technology - Gap Fillers



- **LO Aircraft Require Gap Fillers Between Exterior Panels**
- **Maintainer Exposure Issue During Panel R&R Due to Sanding/Grinding Filler**
- **F-35 Studying Alternative Materials**
 - *Northrop Grumman Awarded AFMC P2 R&D Program*
 - Non-nickel Alternatives
 - *Other Internal R&D Projects*
- **If Successful Alternative Found, Can ESTCP Assist with Cross-Program Qualification/Implementation?**
 - *Unique Program Qualification Requirements will Drive Cost*

Improved Performance Less ESH Impact



Summary



- ***F-35 Largest DoD Weapon System Acquisition Program***
- ***Replaces Several Legacy Aircraft Worldwide***
- ***Operates Under Comprehensive ESH Management and Hazmat Control***
- ***Conducts Aggressive Pollution Prevention and Material Substitution Activities Focusing On Life Cycle Cost Reductions***
- ***Integrates Partner Country Requirements into Program***