F-35 Corrosion Program

Kyle Russell
<table>
<thead>
<tr>
<th>1. REPORT DATE</th>
<th>2. REPORT TYPE</th>
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<tr>
<td>AUG 2011</td>
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<td>00-00-2011 to 00-00-2011</td>
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<th>7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)</th>
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<td>Joint Strike Fighter, Eglin AFB, FL, 32542</td>
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<th>13. SUPPLEMENTARY NOTES</th>
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<td>Presented at the 2011 Air Force Corrosion Conference held 16-18 Aug 2011 at Robins AFB, GA.</td>
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<td>a. REPORT: unclassified</td>
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*Standard Form 298 (Rev. 8-98)*
*Prescribed by ANSI Std Z39-18*
Fleets F-35 will Replace

Domestic and UK

F-16
A-10
F/A-18
F/A-18
AV-8B
Sea Harrier
HARRIER GR7

F-35 Joint Strike Fighter

International

Denmark
Norway
Netherlands
Italy
Turkey
Australia
Canada
Australia

F-16
F/A-18
F-111
AMX
Harrier
Tornado

Domestic and UK Fleets F-35 will Replace

International Fleets F-35 will Replace

DISTRIBUTION STATEMENT A. Approved for public release; distribution is unlimited. JSF11-589
JSF Family Of Aircraft
One Program -- Three Variants
Meeting Service and International Needs

Conventional Take-Off and Landing (CTOL)
- In-Flight Refueling Door (Boom)
- Internal 25mm 4-Barrel Gattling Gun

Short Take-Off and Vertical Landing (STOVL)
- Probe and Drogue Refueling (Basket)
- Lift Fan
- Roll Posts

Carrier Variant (CV)
- Probe and Drogue Refueling (Basket)
- Strengthened Landing Gear and Tailhook
- Wingfold and Ailerons Added

All variants
- 450-600 nm Range
- 1.6 Max Mach (Limit)
- Stealthy
- Same Weapons
- Similar Avionics
- Similar Flight Envelope
- Same Basic Engines

Larger Wing and Horizontal Tail Area
Centerline Gun Pod with 25mm Gun
F-35 Characteristics

- **Key Attributes:**
  - **Stealth**
  - **Integrated Avionics**
  - **A/G Munitions**
  - **Intraflight DL**
  - **Adv A/C Survivability**

- **General Features**
  - **Single seat**
  - **Speed:** 750 kts or 1.6M
  - **Ceiling:** 50,000 ft+
  - **Engine:** PW F135; FET F136

- **Sensors**
  - **Fully integrated open architecture system**
  - **A/G – A/A radar/SAR**
  - **Electro Optical A/G Targeting system**
  - **A/A IRST**
  - **Electronic Support Measures (ESM)**
  - **Short range EO spherical coverage**

**CTOL**
- Length: 51.4 ft
- Wing Area: 460 ft²
- Weight (Empty): 29,036 lbs
- Internal Fuel: 18,840 lbs
- Range: 600 + nm

**STOVL**
- Length: 51.1 ft
- Wing Area: 460 ft²
- Weight (Empty): 32,161 lbs
- Internal Fuel: 14,003 lbs
- Range: 500 + nm

**CV**
- Length: 51.4 ft
- Wing Area: 668 ft²
- Weight (Empty): 32,072 lbs
- Internal Fuel: 20,085 lbs
- Range: 600 + nm

**LETHAL SURVIVABLE SUPPORTABLE INTEROPERABLE**
JSF Team
Prime and Major Sub-Contractors

**NORTHROP GRUMMAN**
- Center Fuselage
- Weapons Bay Door Drives
- Arresting Gear
- Carrier Version (CV) Control and Test
- Radar
- Software
- Low Observable Support System
- Training Courseware and Management Systems

**BAE SYSTEMS**
- Aft Fuselage
- CV Wing Fold
- Fuel System
- Crew Escape
- Life Support
- EW System
- U.K. Support Center
- Throttle/Side Stick
- Horizontal/Vertical Tails
- Flight Control Computer
- STOVL Control and Test
- U.K. Rqts/Stores/SW

**LOCKHEED MARTIN**
Prime Contractor
- Air System Verification
- System Integration
- Mate Through Delivery
- Edges & Control Systems
- Autonomic Logistics
- Mission Systems
- Vehicle Systems
- Training System
- Forward Fuselage
- Wing

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The Pipeline

- Approximately 100 Aircraft in Flow (LRIP 1 – LRIP 5)
- Will Have Fielded ~ 50 Aircraft by The End of CY12
  - *Will need pilots and maintainers trained through the ITC to support Fleet expansion*

Academic Training Center  

JSF Squad Ops/AMU Hangars
Corrosion Program
Background

- HASC directed OSD Office of Corrosion Policy and Oversight to conduct an evaluation of the F-35
  - *Corrosion Evaluation Team (CET) assembled*
  - *Conducted site reviews at JPO and 5 contractor facilities*
  - *Similar reviews were also conducted at F-22 sites*

- CET findings reported back to the HASC
  - *Drawn extensively from F-22 lessons learned*
  - *F-35 JPO response provided as an attachment to the report*
CET Finding
Change Management

- **CET Concern:** Risk that equipment tested to lower corrosion requirements based on location will not be re-qualified to standard corrosion requirements if location or orientation is changed.

- **JPO Response:**
  - *CM Plan requires JPO concurrence of Major B changes*
  - *JPO participates in LM Change Request (CR) technical reviews*
  - *All changes affecting materials must be evaluated by M&P IPT*
  - *Changes potentially affecting corrosion are reviewed at F-35 Corrosion Prevention Advisory Boards (CPAB)*
    - Includes equipment location changes
  - *Many opportunities to identify risk resulting from change*

Program has Insight into Changes Affecting Corrosion - Has Taken Recent Action to Participate in Early CR Reviews

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**CET Finding**

**Use of Magnesium**

- **CET Concern:** Aircraft magnesium components are interfaced with aluminum engine anodized gearbox which is not primed/top-coated.

- **JPO Response:**
  - *Magnesium components are coated with best practice coatings*
  - *Additional surface barrier requirements being pursued for gearbox*
  - *There are very few Mg components on the aircraft*

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**Program Acknowledges CET Finding –
Is Pursuing Additional Surface Barrier Protection on the Gearbox**

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CET Finding

Use of Magnesium

- **CET Concern:** Components qualified by similarity rather than test.
- **JPO Response:**
  - *Most challenging component was tested by full-scale testing*
    - Chosen based on geometry, environment, location
  - *Design incorporated best performing coating based on test results*
    - Other components were qualified by similarity using updated coatings
    - No additional testing is currently planned
  - *JPO and LM continually evaluates new coatings/technologies for future improvements*
CET Finding
Use of Non-Chromated Paint

- **CET Concern**: Use of water-borne non-chromated primer, especially in non-inspectible areas.

- **JPO Response**:
  - *Primer selected in 2004 tested to military coating spec requirements*
    - Best non-chromated primer (with low VOCs) available at time
  - *Initiated independent testing of baseline primer to failure to compare to legacy chromate failure modes (2010)*
    - May increase required inspections if baseline primer with topcoat is not as effective as 1-2 coats of chromate primer used on legacy
  - *White topcoat is used in all fuselage bays—further reducing risk*
  - *Use of chromated primer in non-inspectible areas still under review*
  - *Assessing DoD/industry R&D efforts of other non-chromated primers*
    - Pursue improvement if/when technology readiness warrants
CET Finding
Flexure Testing

- **CET Concern:** Corrosion Testing does not include fully representative operational situations (flexing of joint under loading conditions).

- **JPO Response:**
  - *Conductive gap filler qualification testing included severe spectrum fatigue testing as part of environmental testing*
    - Most susceptible coating component to cracking on legacy platforms
  - *Representative coatings/gap filler on CG-1 full-scale drop test*
    - Inspections of critical joints have shown no significant damage to coatings during severe aircraft carrier landing conditions
  - *Representative coatings/gap filler installed on F-16 flight test bed*
    - Inspections have not shown joint issues
  - *F-18 carrier-based flight testing of LO topcoat in-work*
  - *There is no current test standard to perform this test*

Program Acknowledges Legacy Program Challenges – Has Taken Steps to Minimize Risk via Surrogate Platforms
• CET Concern: The climatic test may be cut/reduced in scope and may not fully test drainage and corrosion performance.

• JPO Response:
  – The program will not reduce climatic test duration / scope
    • Validated during Summer 2010 Tech Baseline Review
    • Decision made after completion of CET site reviews
  – Will incorporate legacy program lessons learned
    • Specific interest in assessing internal drain paths

Program Actions Have Mitigated CET Concern – Robust Climatic Test Planned Incorporating Lessons Learned
CET Finding
Life Cycle Cost Methodologies

- **CET Concern:** Life cycle cost assessment methodology used for trade studies does not specifically account for corrosion impacts.

- **JPO Response:**
  - *Program method is a parametric based on multiple legacy programs which does not specifically break out corrosion*
    - Similar to methods used for other legacy programs
  - *Will continue to pursue improved modeling*
    - Surveyed Office of Corrosion Policy and Oversight website
    - Working with the CET did not realize better LCC models
    - Will assess whether current legacy program realities can influence current parametric based models

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Program Acknowledges CET Concern – Will Continue to Work with OSD to Improve Techniques

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Lessons Learned from F-22

**Design**
- Reduced use of conductive gap fillers
  - Fewer than 25% of permanent gaps use conductive gap filler
- OML coatings/materials use that are not galvanically dissimilar
  - System requirements retain risk—not as dissimilar as F-22 baseline
- Ensure sufficient internal drainage system
- Specific use of design best-practices to minimize corrosion:
  - Elimination of aluminum honeycomb
  - Fiberglass barrier ply at composite/aluminum interfaces

**Process**
- Greater participation in industry change management process
- Integration of “standard” and signature M&P communities
- Active management and use of CPAB expertise
  - Active participation in F-22 CPAB exchanges
Lessons Learned from F-22

• Test
  – Inclusion of sulfuric salt spray and increased neutral salt spray for materials and systems qualifications
  – Early corrosion testing of conductive gap filler in a representative operational environment.
  – Extensive testing of full stack-up panel seams with simulated damage exposed to accelerated and outdoor (beach) exposures
  – Maintaining a robust full scale climatic test
Summary

- The F-35 has a comprehensive corrosion prevention program
  - Leveraged legacy aircraft design lessons learned
  - Integrated the best processes from Navy and Air Force standards
  - Focused on early assessment of materials in an operational environment
  - Maintains active engagement in technology development communities

- The Summer 2010 Technical Baseline Review validated approach
  - No significant gaps in design or testing were identified

- Corrosion is always a systems engineering trade
  - Suggests a “corrosion-proof” aircraft is unlikely
  - Resulting “corrosion-resistant” design improved over legacy LO aircraft

- The CET required the JPO to broadly review/defend prior decisions
  - Technical consensus of findings did not occur in all cases
Questions?