
JOINT STRIKE FIGHTER
F-35
LIGHTNING II
LETHAL SURVIVABLE SUPPORTABLE AFFORDABLE
DEPARTMENT OF DEFENSE
UNITED STATES OF AMERICA
DEPARTMENT OF THE NAVY
UNITED STATES MARINE CORPS
DEPARTMENT OF THE NAVY
UNITED STATES OF AMERICA
DEPARTMENT OF THE AIR FORCE
UNITED STATES OF AMERICA
F-35 Corrosion Program
Kyle Russell

Fleets F-35 will Replace

Domestic and UK


F-16


A-10

USAF


F/A-18 — USN


F/A-18


AV-8B

USMC


Sea Harrier


Harrier GR7

RN/RAF

F-35 Joint Strike Fighter

International

Denmark
Norway
Netherlands
Italy
Turkey

F-16

Australia
Canada

F/A-18

Australia — F-111

Italy

AMX

Harrier

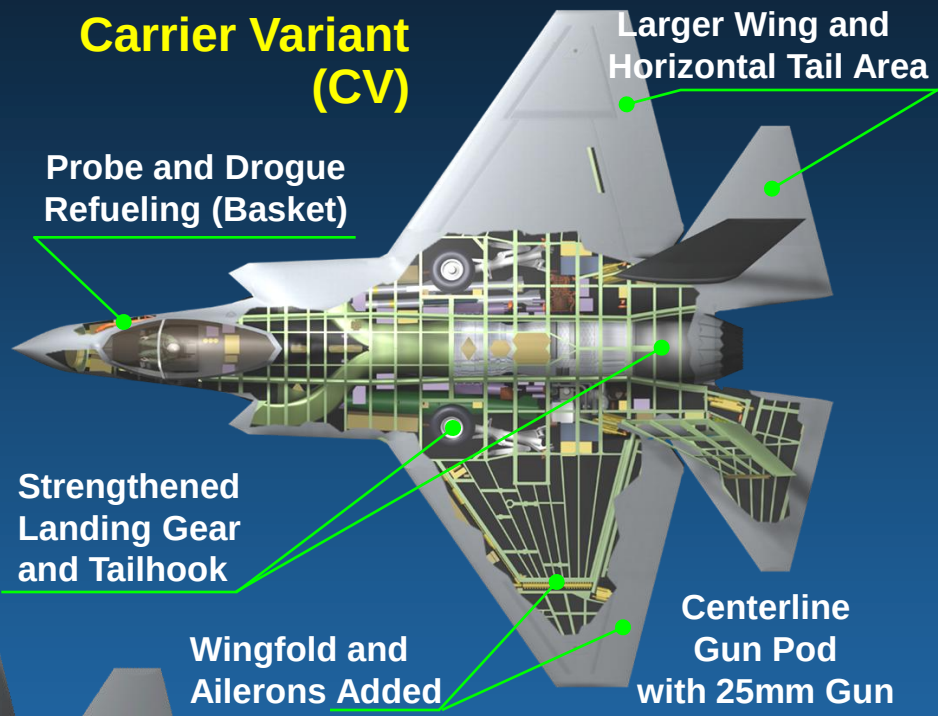
Tornado

JSF Family Of Aircraft

One Program -- Three Variants
Meeting Service and International Needs

Conventional Take-Off and Landing (CTOL)

Carrier Variant (CV)



Short Take-Off and Vertical Landing (STOVL)

All variants

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

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***

Length: 51.4 ft
Wing Area: 460 ft^2
Weight (Empty): 29,036 lbs
Internal Fuel: 18,840 lbs
Range: 600 + nm

Length: 51.1 ft
Wing Area: 460 ft^2
Weight (Empty): 32,161lbs
Internal Fuel: 14,003 lbs
Range: 500 + nm

Length: 51.4 ft
Wing Area: 668 ft^2
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

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

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***

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

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***

Program Qualification Testing Approach Effective - Thorough Assessment of Most Challenging Component

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 Finding
Full Scale Climatic Testing

- **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

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

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***

F-22 Lessons Learned Have Been Realized –
Many Industry/Government SMEs Have Transitioned to F-35

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***