478th Aeronautical Systems Wing

Delivering 21st Century Air Dominance!

Aircraft Structural Integrity and the F-22

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4-6 December 2007

U.S. AIR FORCE

Outline

- Program Overview
- Why is ASIP Important?
- ASIP on the F-22
- Lessons Learned
- Way Forward
- Summary

(U.S Air Force photo by Staff Sgt Eric T. Sheler)

Program Overview

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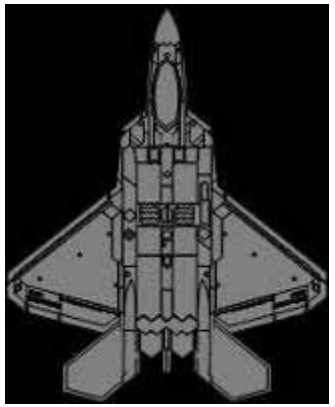
Program Overview
Aircraft Characteristics

- **Primary Function: Air dominance, multi-role fighter**
- **Wingspan: 44 feet, 6 inches**
- **Length: 62 feet, 1 inch**
- **Height: 16 feet, 8 inches**
- **Weight: 19,700 pounds**
- **Maximum Takeoff Weight: 83,500 pounds**
- **Power Plant: Two Pratt & Whitney F119-PW-100 turbofan engines**
- **Speed: 1,140 mph (Mach 1.72); supercruise at altitude**
- **Armament:**
  - **1 M61A2 20-millimeter cannon**
  - **2 AIM-9 infrared missiles in side weapon bay**
  - **6 AIM-120 AMRAAMs in main weapon bay**
    - **or 2 GBU-32 JDAMs and 2 AIM-120 AMRAAMs**



***Information taken from public Air Force website (www.af.mil)**

Program Overview
How goes it in 2007

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First F-22 Multi-year Contract

First Red Flag Participation

100th F-22 Rolls-out

F-22's Permanently in AK

Sheppard Schoolhouse Opens

First F-22 deployment overseas

F-22 wins Collier Trophy

Program Overview

F-22 Program Schedule

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FY 86 87 88 89 90 91 92 93 94 95 96 97 98 99 00 01 02 03 04 05 06 07 08 09 10 11 12 13

Milestones

- Milestone I (750 a/c) Dem/Val Start
- Major Aircraft Review
- Milestone II (648 a/c) EMD Start
- Bottom Up Review (442 a/c)
- QDR (339 a/c)
- LRIP Authorization
- OT&E Phase 1 (Oct 03)
- IOT&E Start (Apr 04)
- Full Rate Production Decision (Mar 05)
- FOT&E Complete (Nov 05)
- IOC (Dec 05)
- FOT&E(2) (May 07)

Demonstration / Validation

- YF-22 First Flight 9/90
- YF-23 First Flight 8/90

Engineering and Manufacturing Development

- First Flight EMD
- 9 Flight Aircraft (1 Static and 1 Fatigue Aircraft)
- T&E/ OT&E

Production Representative Test Vehicles

PRTV I	2
PRTV II	6

Production Quantities

MY (7-9)

Lot Delivery Quantities

FY07 PB	10	13	21	22	24	24*	20	20	20
Lot	1	2	3	4	5	6	7	8	9

Sustainment

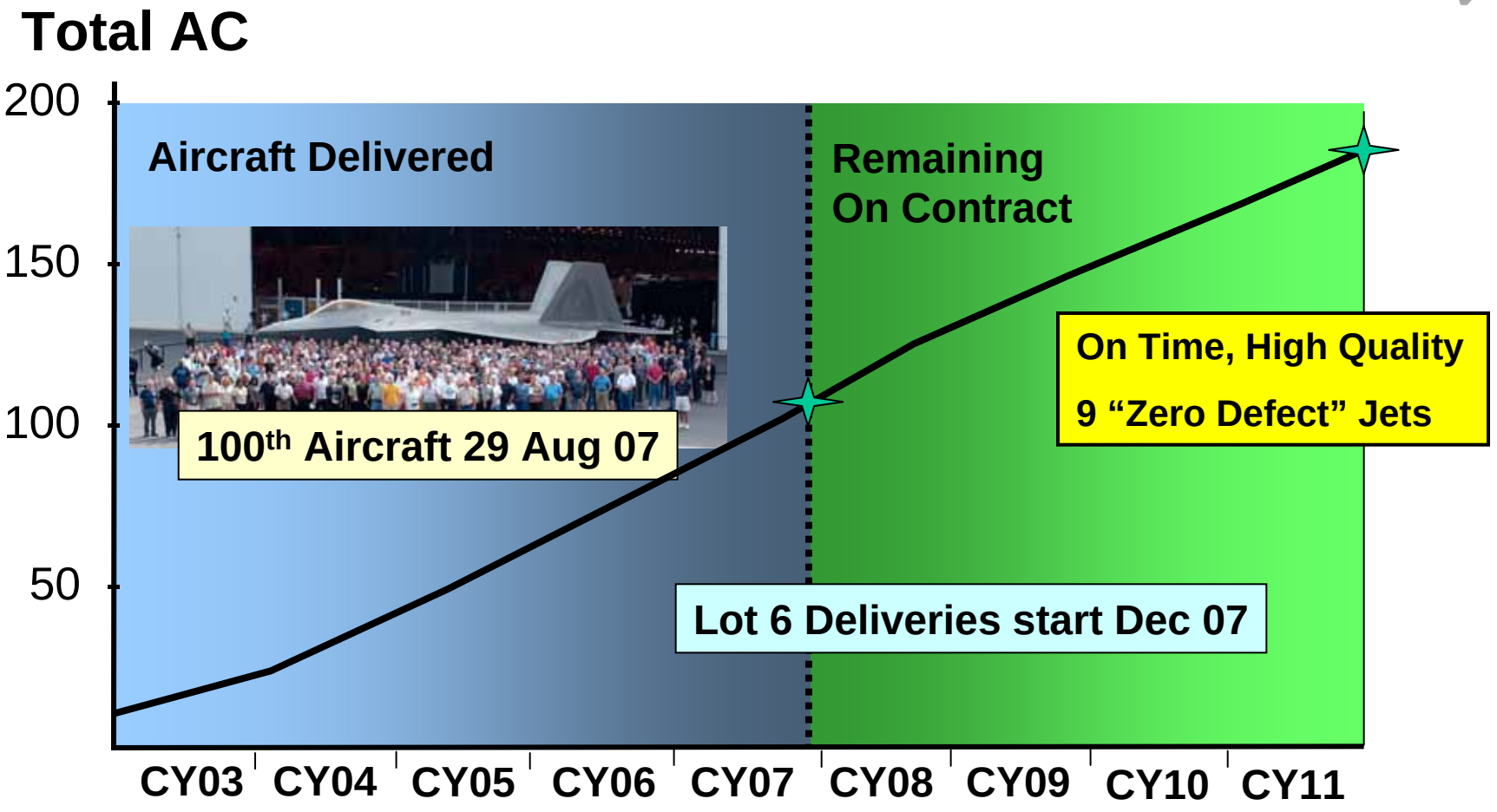
Annual PALS/FS&T | Long Term PBL

Beddown

Nellis | Tyndall | Langley | Elmo | Hmn | Hickam

* Lot 6 quantity includes RTA

Program Overview
Production Program of Record



100% of Production on Contract and Over 50% Delivered

Program Overview

F-22 Basing Plan

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Why is ASIP Important?

- **Delivering 21st Century Air Dominance**
  - **Our Vision: "To provide the warfighter with the most capable and available fighter in the world…the F-22"**
- **F-22 ASIP provides the means to achieve:**
  - **Flight safety and mission effectiveness**
  - **Proactive approach to force management**
  - **Risk mitigation**

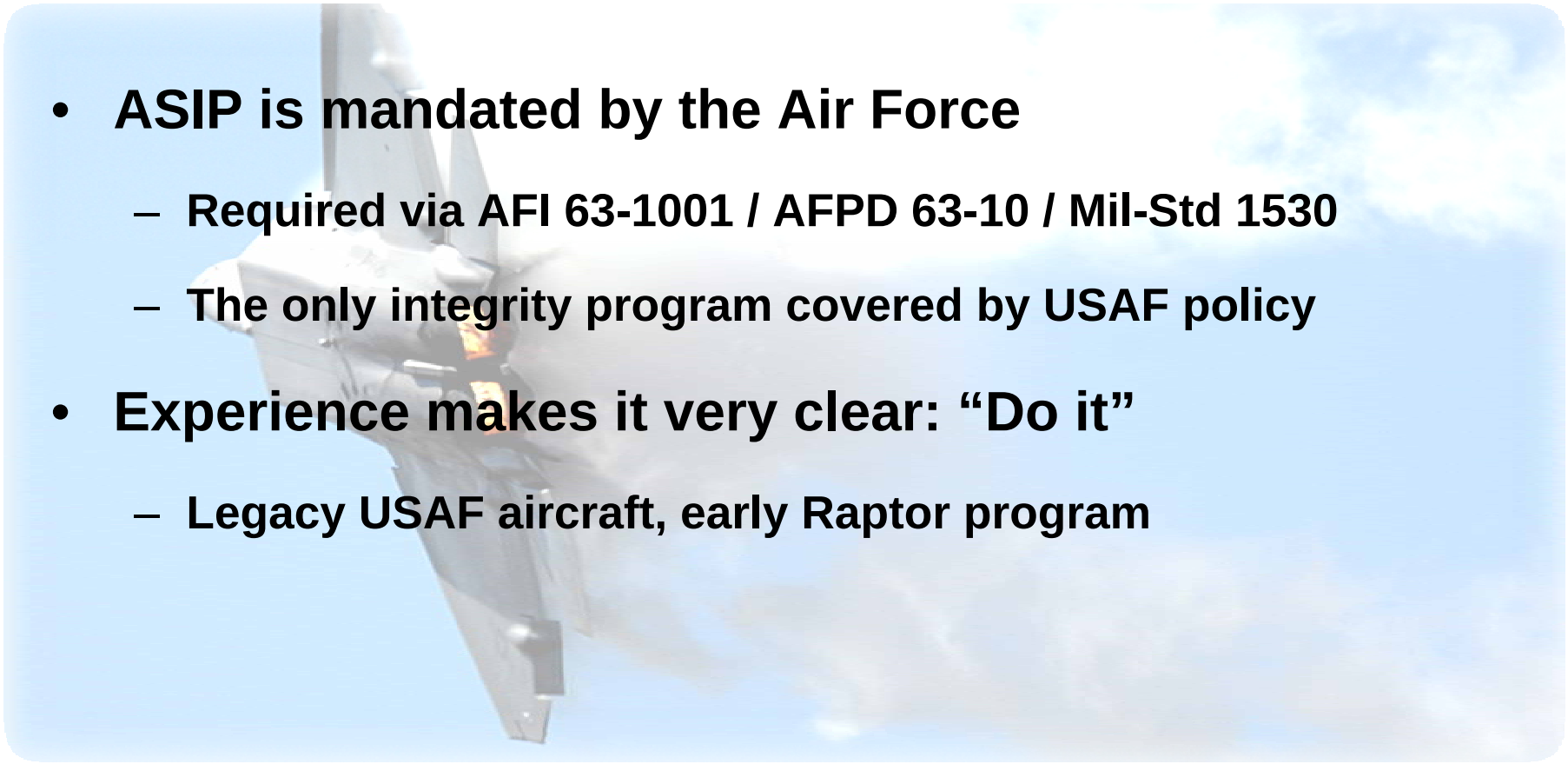
(www.af.mil, U.S. Air Force photo/Tech Sgt Justin D. Pyle)

Why is ASIP Important?

- **Delivering 21st Century Air Dominance**

(www.af.mil, U.S. Air Force photo/Tech Sgt Justin D. Pyle)

Why is ASIP Important?



- **ASIP is mandated by the Air Force**
  - **Required via AFI 63-1001 / AFPD 63-10 / Mil-Std 1530**
  - **The only integrity program covered by USAF policy**
- **Experience makes it very clear: “Do it”**
  - **Legacy USAF aircraft, early Raptor program**

(www.af.mil, U.S. Air Force photo/Tech Sgt Justin D. Pyle)

Why is ASIP Important?

Proactive approach to force management

- Ensures structural integrity throughout service life
  - Accurately accounts for fleet variation of usage and loads environment
- Enables flexible response to force management issues
- Reduces operational risk and maintenance impact
  - Supports planning of future maintenance actions
  - Minimizes maintenance effort required for inspections
  - Improves accuracy of analytical predictions through repetitive verification
- Provides effective data base to support modernization changes
- Provides useful data for external programs (e.g. F-35)
- Reduces life cycle cost

(www.af.mil, U.S. Air Force photo/Tech Sgt Justin D. Pyle)

ASIP on the F-22
Engineering/Production Concurrency

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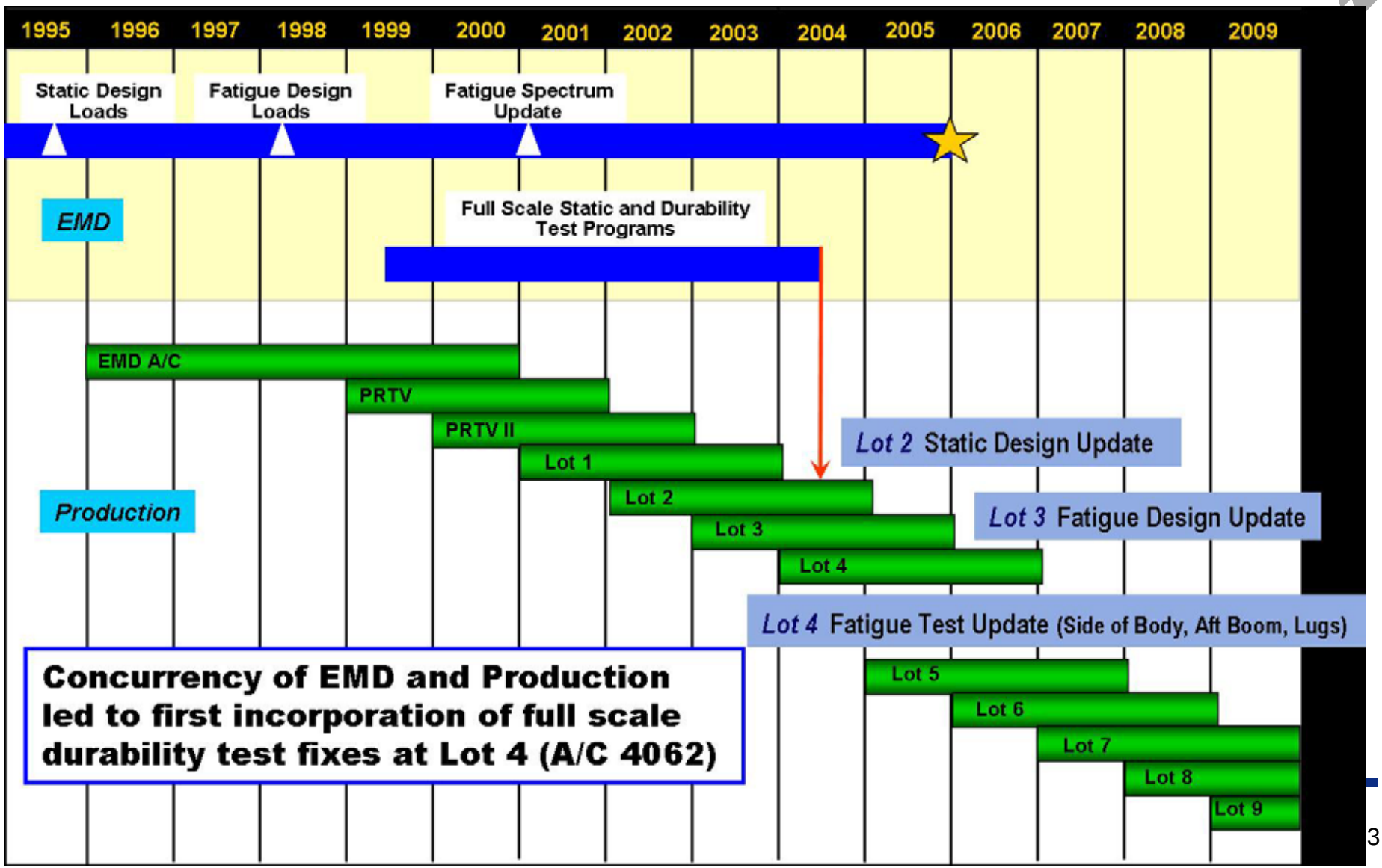
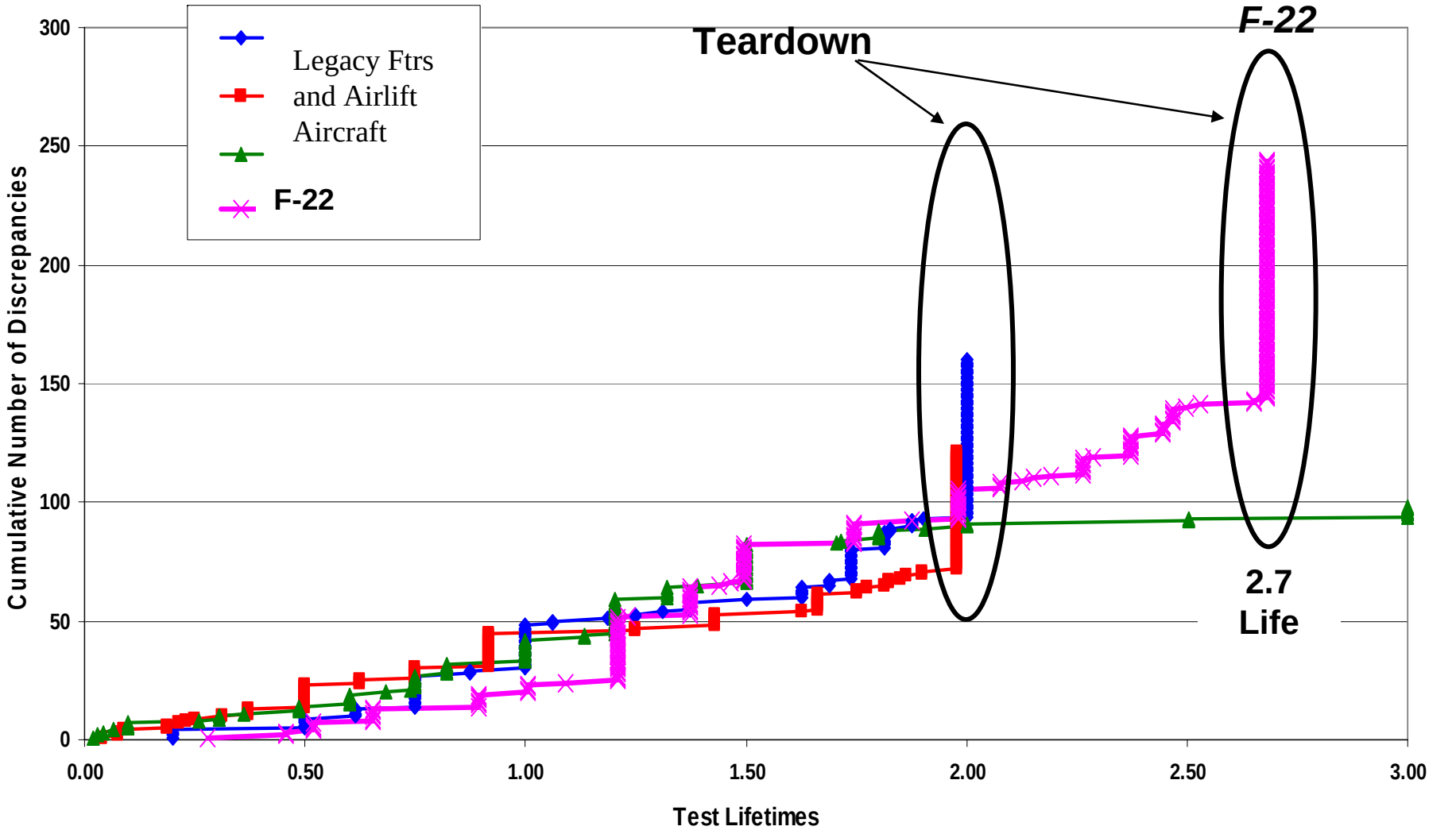
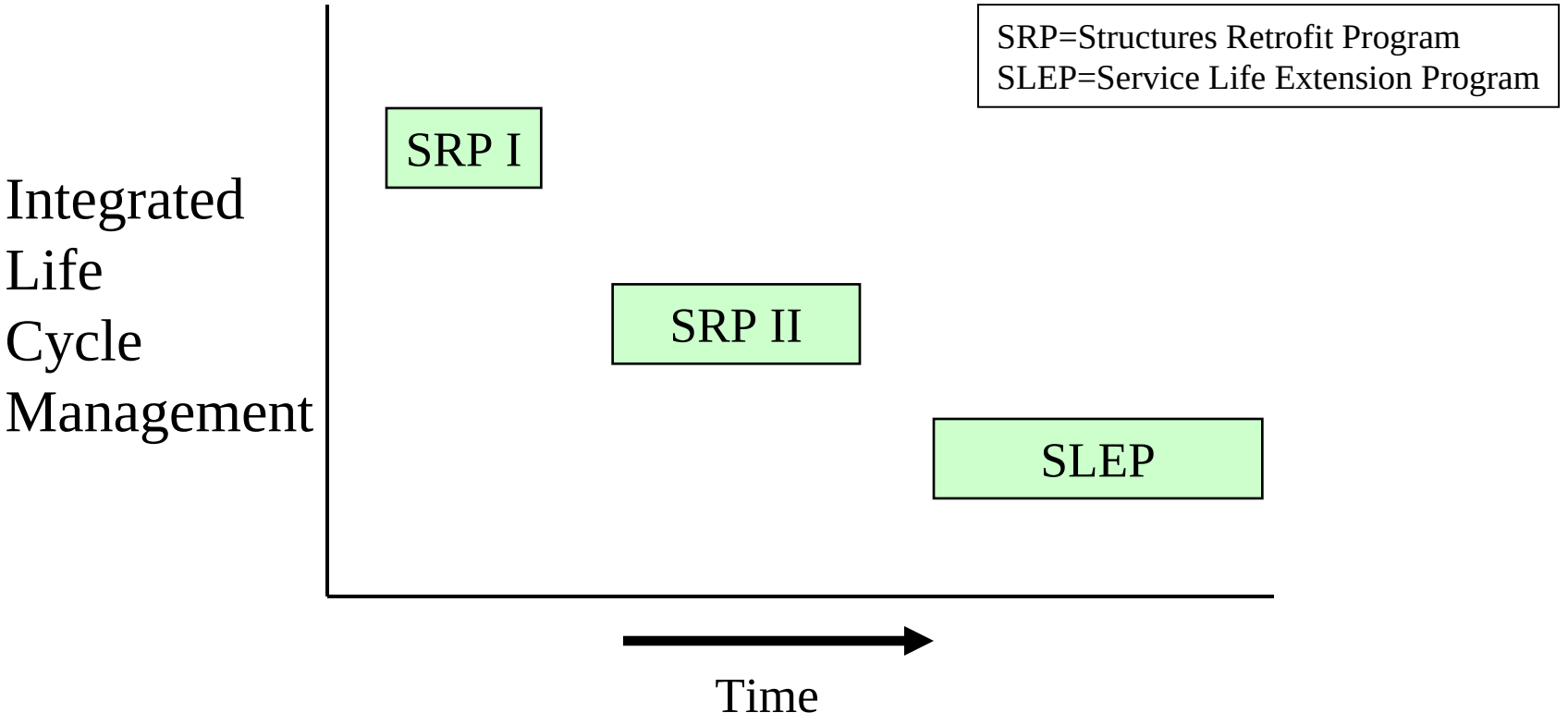


ASIP on the F-22
Fatigue Test Experience



F-22 Test Results Led to Proactive Structures Retrofit Program

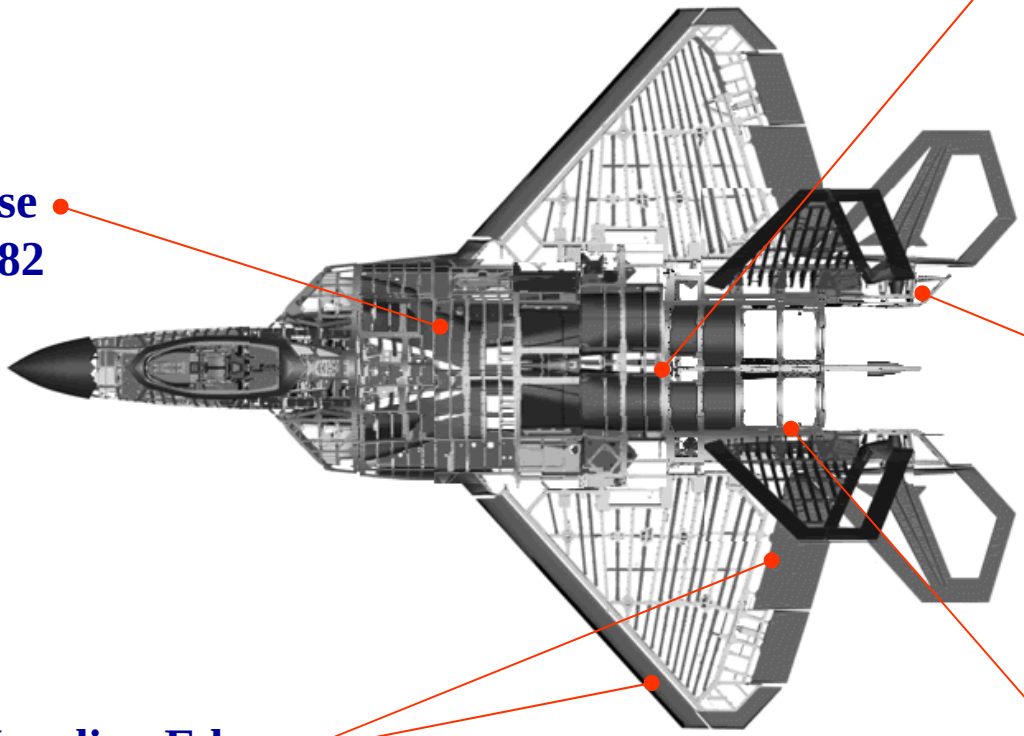
ASIP on the F-22
F-22 Structures Management



Plan early and Educate Stakeholders on Requirements

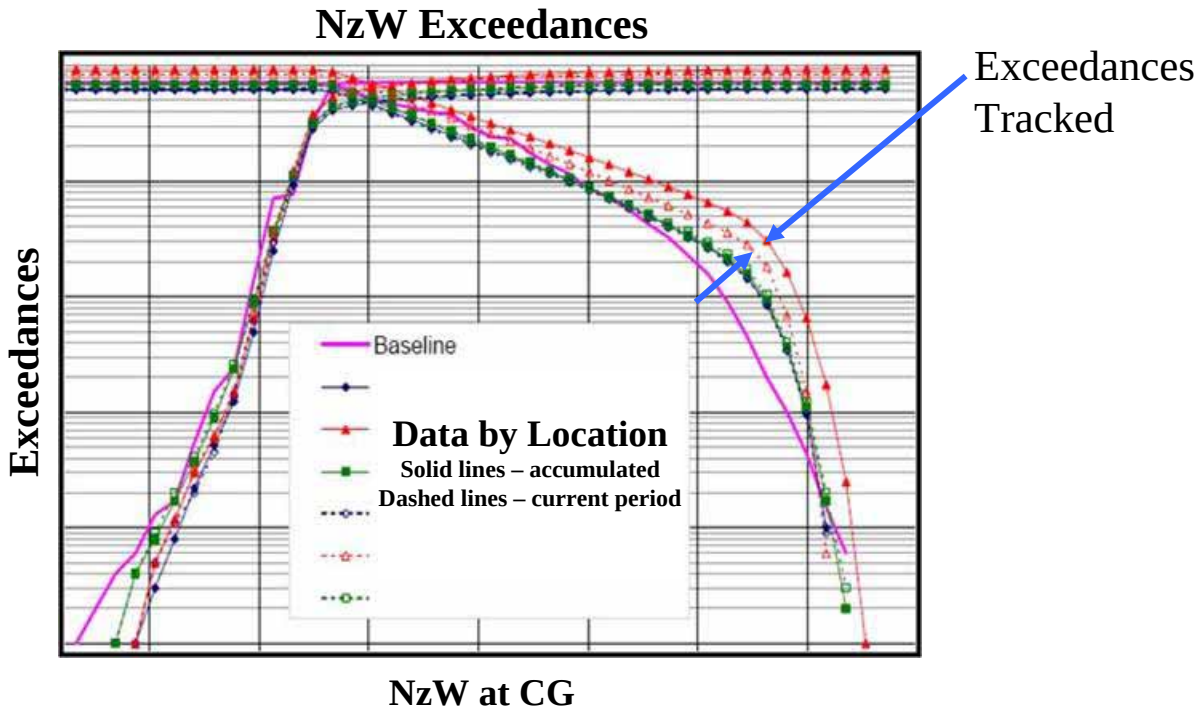
ASIP on the F-22

Production Changes From Fatigue Test & Analysis



ASIP on the F-22
Aircraft Usage

- F-22's flown at high G's and heavy weight
  - NzW = Vertical Load Factor x Aircraft Gross Weight: primary loads driver for many structural critical locations
- Risk: Reduced aircraft availability; more inspections, more mods



Fleet Usage Data Allows Proactive Management Actions

ASIP Progress on the F-22

- **Task I – Design Information**
  - Complete
- √ **Task II – Design Analyses and Development Tests**
  - Open analyses: Final EMD spectrum, weight growth study, durability and damage tolerance updates, lug bore
  - Open testing: Lug bore element tests, full scale frame tests, ground vibration test
  - Open development: Non-destructive Inspection (NDI) technology
- **Task III – Full Scale Testing**
  - Complete
- **Task IV – Force Management Data Package**
  - Complete, will require periodic updates
- √ **Task V – Force Management**
  - Ongoing until A/C retirement

(U.S. Air Force photo/Tech. Sgt. Shane A. Cuomo)

Lessons Learned

Development/Production Concurrency

- **Program concurrency implemented to deliver F-22 operational capability early**
  - **60 aircraft delivered prior to completion of fatigue test**
  - **Delayed incorporation of "in-line" production improvements**
  - **Configuration changes required for early aircraft**

- ***Lesson:* Programs need to plan for retrofit activities post EMD to cover concurrency shortfalls**

(U.S. Air Force photo by Kevin Robertson)

Lessons Learned
Building Block Component Testing

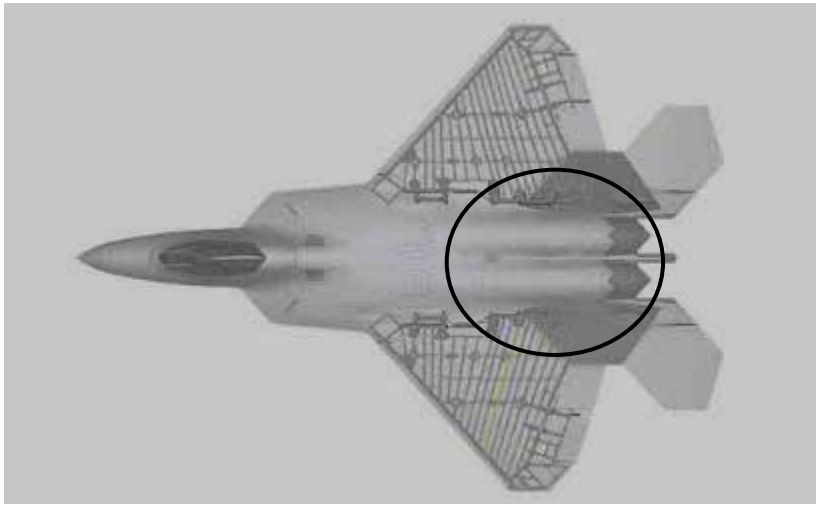
- **Forward boom assembly component test was reduced to streamline program and reduce costs**
  - **Lug bore and lug radii cracks found during full scale fatigue testing late in EMD**
  - **Structural analysis was correlated to sub-scale test specimens and did not adequately predict stress levels of the full scale structure**
  - **Originally planned component test would have identified problems in early EMD**

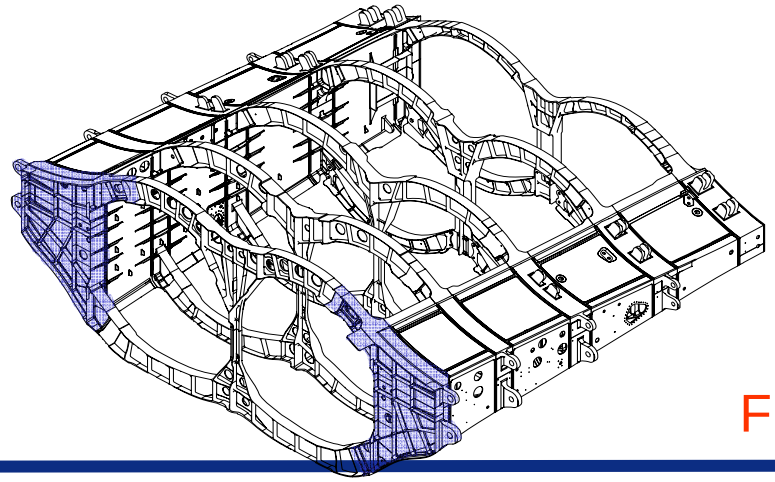
- ***Lesson:* Building block test would have identified problem early and prevented higher maintenance/quality control costs**

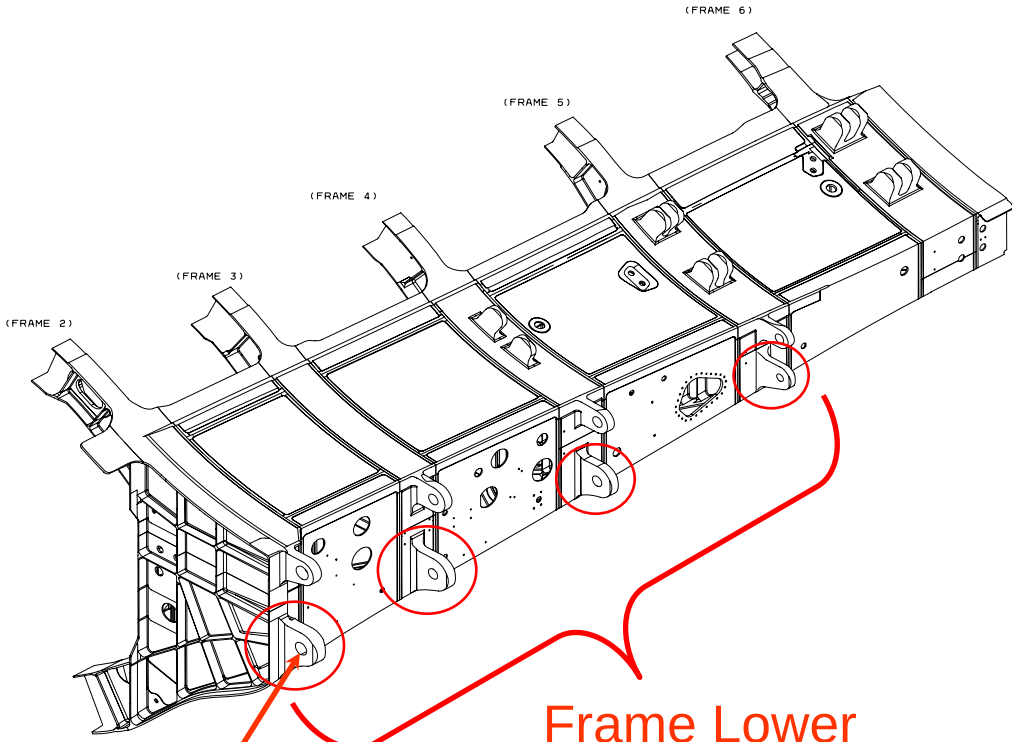
(U.S. Air Force photo by Kevin Robertson)

Lessons Learned

Building block approach







Frame Lower Radii Cracks

Frame 2 Lug Bore

Lessons Learned
Scale-up of Structural Castings

- **Large titanium castings were not adequately developed prior to production transition**
  - **Manufacturing scale-up issues not found until production**
    - **Rigorous NDI implemented in production to assure quality**
    - **New damage tolerance analysis methodology developed**
    - **Wing side of body casting redesigned as a forging**

- ***Lesson:* Manufacturing scale-up of proven technologies not exempt from rigorous steps to successfully transition into production**

(U.S. Air Force photo by Kevin Robertson)

Lessons Learned
Materials/Analysis Methodology

- **Material selection challenged analysis methodology and NDI capability**
  - **Methodology**
    - **New analytical approaches required for Beta titanium due to large grain size**
    - **Poor life predictions using existing crack modeling techniques**
  - **NDI**
    - **Response variation due to grain size and surface treatments**
    - **Geometries and access restrictions (systems and Low Observables Coatings) drove new technology development**

- ***Lesson:*** **New materials need to be fully characterized and methodology adapted to handle new materials and geometries.** ***NDI capabilities need to be a consideration during design.***

(U.S. Air Force photo by Kevin Robertson)

Lessons Learned

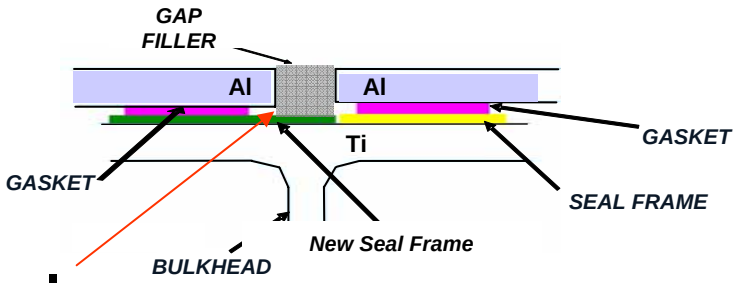
- **Panel corrosion discovered on fielded aircraft after extended exposure to moist environment**
  - **Galvanic re-action with gap filler and exterior aluminum panels**
    - **Corrosion confined to specific aluminum panel skin joint areas**
    - **Structural integrity implications if not corrected**
  - **Multi-faceted repair & prevention plan underway**

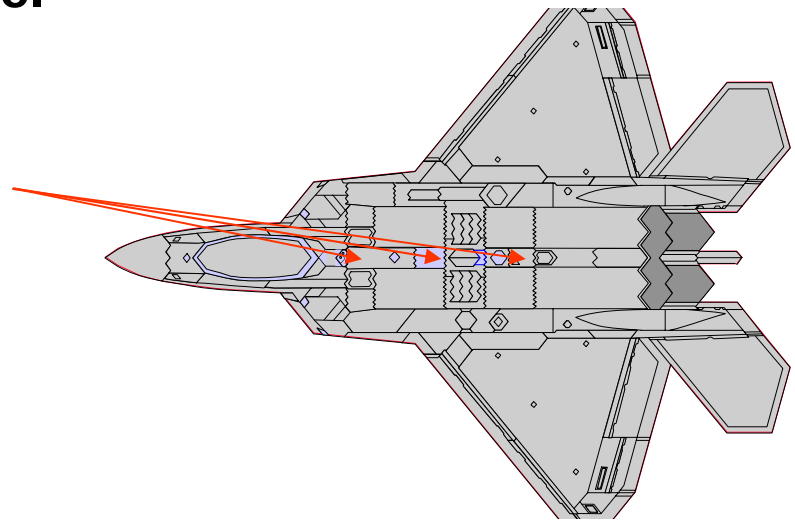
- ***Lesson:*** **Full scale system exposure to relevant operational environments early in test program would have drove earlier design/retrofit mitigation procedures and reduced "clean-up" costs**

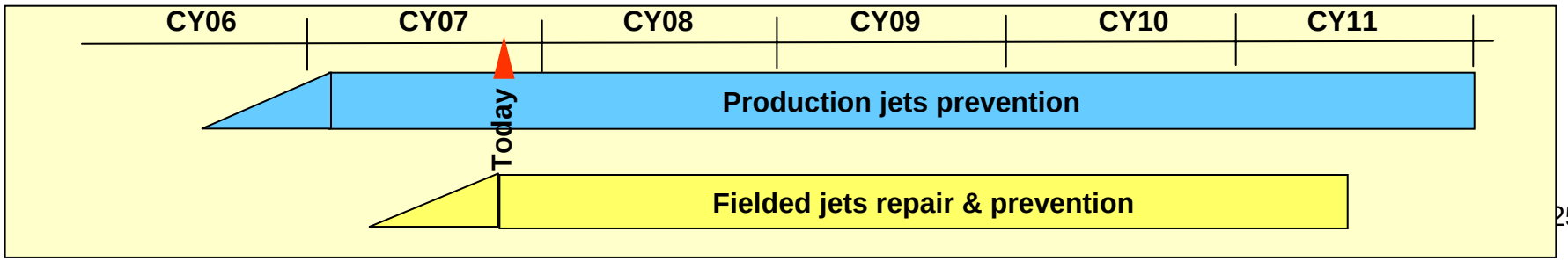
(U.S. Air Force photo by Kevin Robertson)

Lessons Learned
Corrosion Prevention Plan

- **Corrosion mechanism well understood & characterized**
  - **Galvanic action with gap filler, exterior aluminum panels & panel attach areas**
  - **Corrosion confined to specific aluminum panel skin joint areas**
- **Multi-faceted repair & prevention plan executing since CY06**
  - **Low program risk**







Lessons Learned
Corrosion Prevention Plan - Near Term

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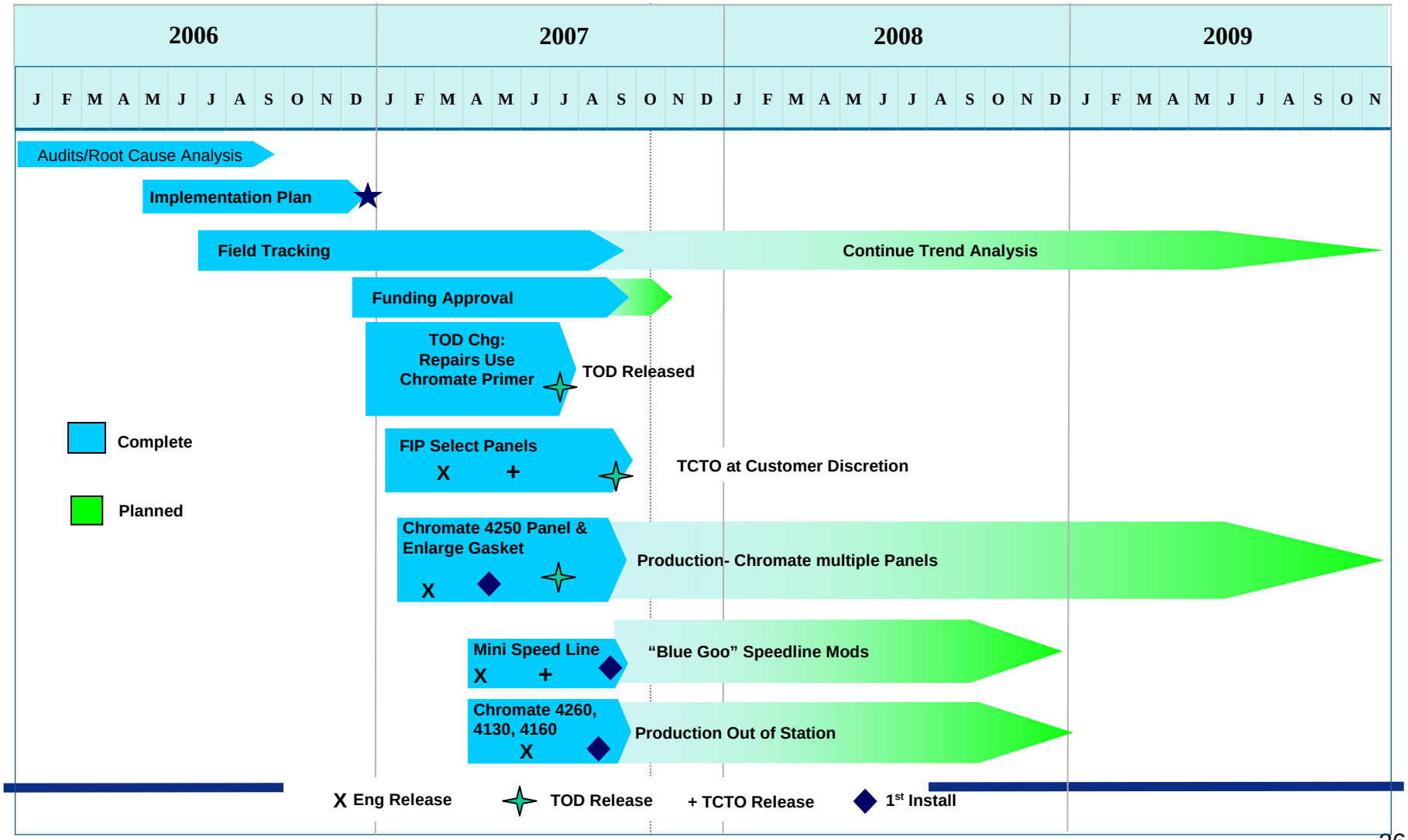

Way Forward
Structural Retrofit Programs

- **Structural Retrofit Programs (SRP) will bring early production aircraft up to full service life configurations**
  - **SRP 1**
    - **In progress at depots**
    - **Addresses the most time critical locations**
  - **SRP 2**
    - **In development and planning – will address remaining critical locations**
    - **Cost Benefit Analysis approach to prioritize retrofit locations**

(U.S. Air Force photo/Tech. Sgt. Ben Bloker)

Way Forward
SRP Development

- **Continue F-22 test programs to support SRP**
  - **Lug bore element testing - completed**
    - **Successfully verified cold work expansion provided sufficient benefit to meet design service life requirement**
  - **Frame crack growth tests**
    - **Component frame tests to evaluate crack growth data on wing attach frames not obtained during full scale fatigue test**
  - **Frame peening evaluation**
    - **Additional component frame testing to verify and select best fatigue enhancement method to extend service life of wing attach frames**

(U.S. Air Force photo/Tech. Sgt. Ben Bloker)

Way Forward
Specific ASIP II Tasks

- **F-22 ASIP Projects to complete**
  - **Continuation of coupon testing to further understand F-22 material properties**
  - **Development and verification of new analysis methodology**
    - **Crack growth through residual stress zones**
    - **Shallow gradient crack growth**
  - **Structural loads and analysis update**
    - **Supports modeling effectiveness**
  - **Weight Growth assessments**
    - **Loads, Flutter & dynamics**
    - **Supports new capability insertions**
  - **Organic NDI capability improvement**

(U.S. Air Force photo/Tech. Sgt. Ben Bloker)

F-22 Modernization Plan

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Capability Insertion Roadmap

Increment 2	Increment 3.1	Increment 3.2	Increment 3.3
SS JDAM Full Other Candidates	APG-77 SAR JDAM Retarget SDB Basic Others	Adv Data-link AIM-9X SDB Full Auto GCAS	TBD
Fielded in CY07	In Test	Risk Mitigation	Planning Stage

Completion Dates:

Dev	FY07	FY10	FY13	FY16
Retro	FY10	FY14	FY18	TBD

ASIP Supports Changes to Weapon System

Way Forward
ASIP Task V Projects

- **ASIP TASK V Activities**
  - **High fidelity fleet usage tracking system**
    - **Capture impact to airframe due to modernization**
    - **Package inspections to maximize aircraft availability**
    - **Capture effects of base usage variation (Ex- training fleet)**
  - **Structural certification of upgrades and new stores capability**
  - **Assessing risk to structural baseline due to modernization changes**

(U.S. Air Force photo/Tech. Sgt. Ben Bloker)

Summary

- **ASIP is integral to delivering and sustaining 5th generation fighter capability to the USAF**
- **Multiple challenges remain in ASIP tasks II (development) and task V (sustainment) to ensure robust support of F-22**
- **Several valuable lessons learned can be gleaned for application to other programs**
- **F-22 program has a well defined way forward to assure safety and structural integrity for the service life of the weapon system**

ASIP provides risk reduction and cost avoidance while preserving safety of flight

(U.S. Air Force photo/Tech. Sgt. Ben Bloker)