F-22 System Program Office

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U.S. AIR FORCE

F-22 Force Management; Overcoming Challenges to Maintain a Robust Usage Tracking Program

Wirt Garcia, Robert Bair
F-22 Program
Pete Caruso, Wayne Black,
Lockheed Martin Aeronautics Company

2006 USAF ASIP Conference
San Antonio, Texas
28-30 November 2006

Outline

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- Force Management background
- Challenge 1, L/ESS equation development
- Challenge 2, IAT equation development
- Challenge 3, IAT inspection interval forecast
- Structures Retrofit Plan
- L/ESS report results summary
- IAT report results summary
- TO updating process
- Force Management data comparison
- Conclusion

U.S. Air Force photo/Senior Airman Austin Knox
www.airforce.mil

Force Management Background
Developmental Phase

- **Aircraft 4000 tested to 2.68 lifetimes**
  - **2 Durability**
  - **0.68 Damage Tolerance**
- **Test overlapped production deliveries**
  - **Findings incorporated into production as they were discovered**

Force Management Background
Inspection Burden

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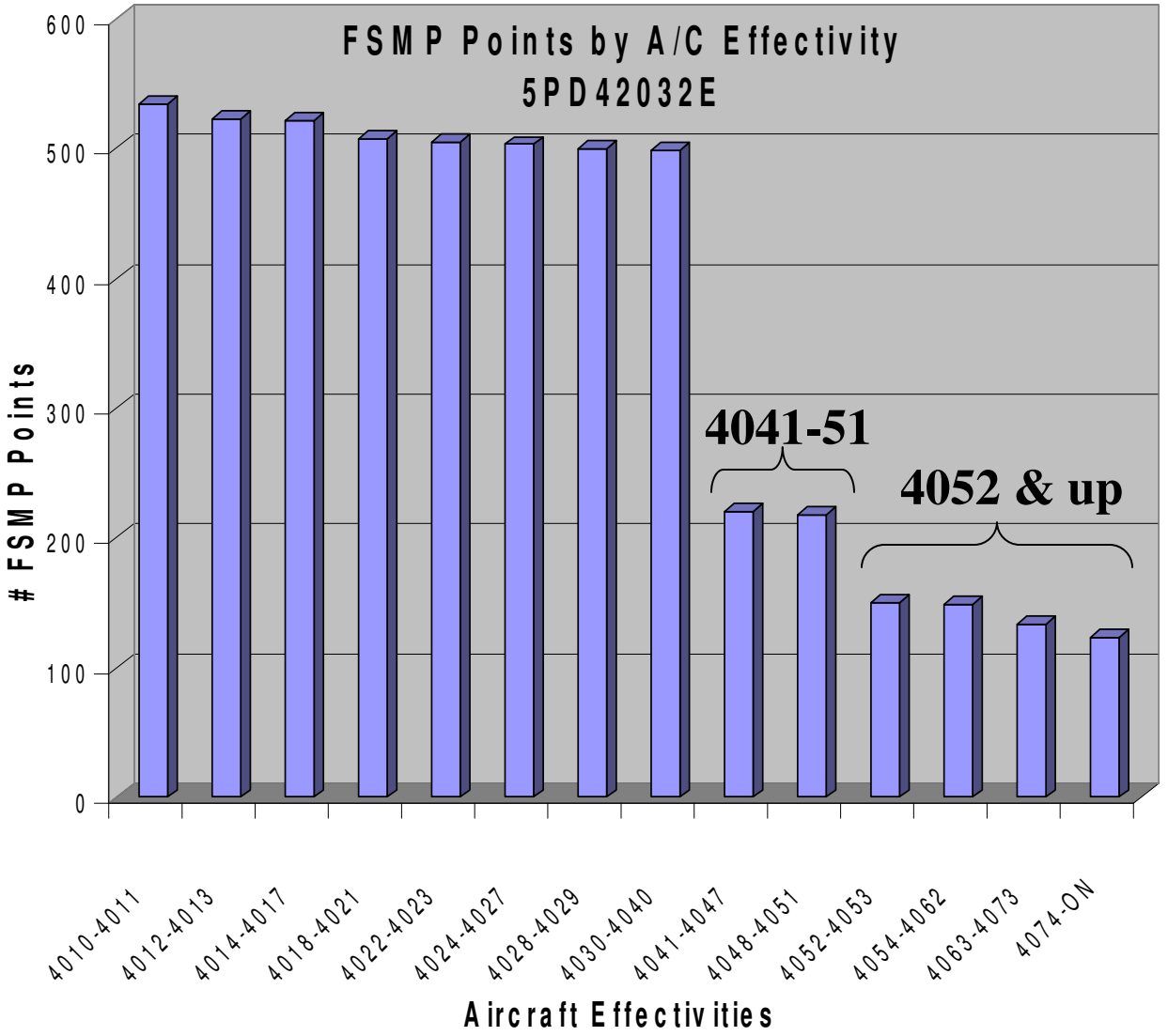

Force Management Background
Current Force Summary (as of 3 Nov 06)

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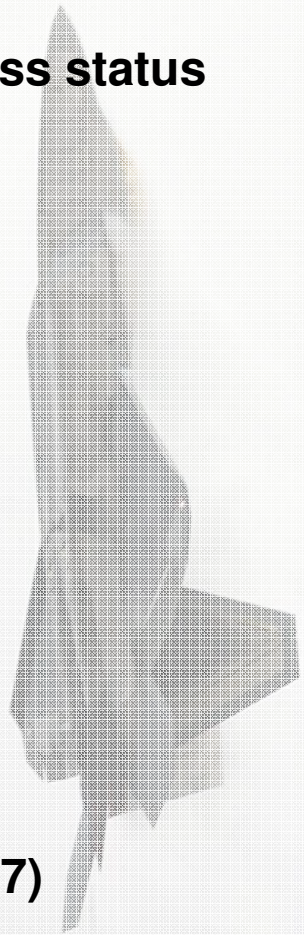
- Total number of aircraft produced to date – 86
  - 6 Aircraft are retired/non flyable or crash/total loss status
    - 5 have been converted to ground trainers
    - 1 was total loss due to mishap (A/C 4014)
- High time aircraft
  - EMD aircraft
    - A/C 4003 – 1,842 hours (No longer flying)
    - A/C 4007 – 1,139 hours (Currently in flying status)
  - Operational aircraft
    - A/C 4011 – 653 hours (Nellis AFB)
- Site activations
  - Test / MX Training: Edwards AFB and Hill AFB
  - Training: Nellis AFB and Tyndall AFB
  - Operational: Langley AFB, Elemendorf AFB (2007)



U.S. Air Force photo /Airman Jonathan Steffen
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Force Management Background

Feedback Loop for Maintaining Integrity & Safety

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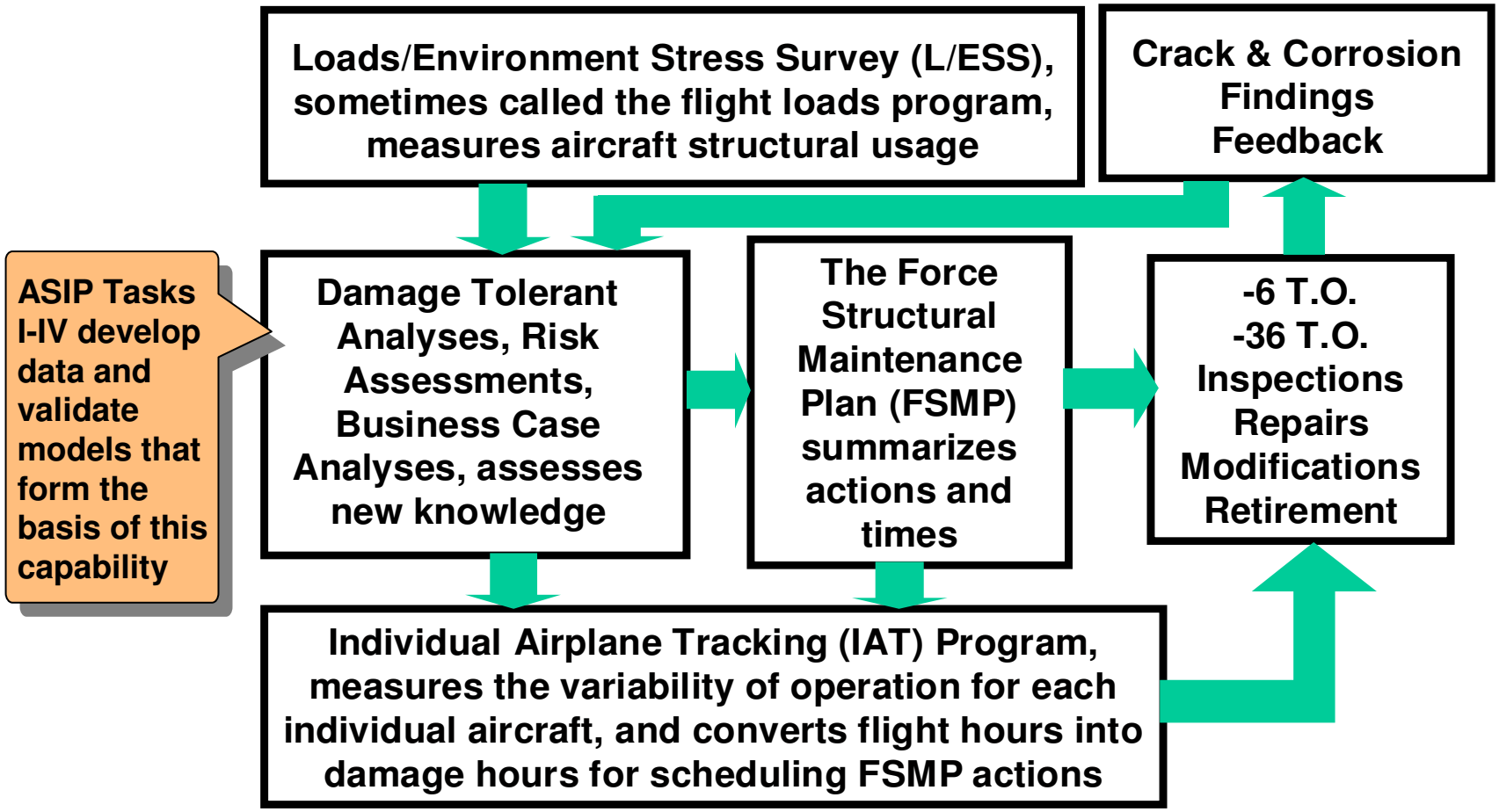

- Process tracks the causes/effects of aging on airframe
- Trend analysis supports updating FSMP to account for new findings

Source: Dr. Joseph Gallagher, ASC/EN

Force Management Background
Data Collection and Processing

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On-Board:

Flight Controls
Stores Management
Fuel Management
Engine Controller
Inertial Reference System
Vehicle Subsystem Controller

→ **Flight Data Recorder (FDR)**

Real time processing of data to retain significant parameters

→ **Data Transfer Cartridge (DTC)**

On-board storage

Ground Interfaces:

Data Transfer Cartridge (DTC)

Pilots removes and provides DTC to maintainer

→ **Integrated Maintenance Information System (IMIS)**

Maintainer downloads DTC data to IMIS

Data is received at contractor site

→ **Integrity Data Analysis and Reporting System (IDARS)**

Data is loaded into IDARS

Data is processed

→ **L/ESS & IAT Reports**

Reports are produced quarterly to support fleet tracking

Force Management Background
Data Collection & Processing

- The FDR records data for every aircraft
- Data is collected after each flight
  - Over 200 analog parameters
  - Over 400 discrete values
  - The same complete data set is used for individual tracking and usage
- Data is recorded at a rate of up to 20 Hz
- FDR is integrated with other systems so that it uses existing aircraft sensors and not FDR dedicated sensors

Challenge 1
L/ESS equation development

- **Fleet-measured data does not match L/ESS predictions**
  - **Load equation extrapolation beyond the regression parameter input space**
  - **Non-uniform regression data distribution**
  - **Unstable L/ESS equations**
- **Buffet loads development**
  - **Wind tunnel model**
    - **Buffet on empennage only, 2 modes on vertical tail/rudder, 2 modes on horizontal tail**
  - **Buffet observed in flight test**
    - **9 vertical tail/rudder buffet modes, buffet on wing surfaces, wider range of modal frequencies, and sensitivity to sideslip**

Recovery Plan for Challenge 1

- **Input regression data-space expanded and uniformly conditioned**
  - **19,000 new load cases correlated to flight test added to existing 125,000 cases**
    - **Expanded maneuver set**
    - **Expanded mach-altitudes**
    - **13,000 cases run on FEM for IAT control point regressions**
  - **102 existing L/ESS equations recalculated**
  - **131 new L/ESS equations added for use in IAT equations**
- **Buffet power spectral density functions redefined**
  - **All appropriate modal shapes can participate**
  - **Wing surfaces added**
  - **Sideslip factors added**

Challenge 2
IAT equation development

- **Scope of task**
  - Over 600 control point equations
  - Load equations were initially not available
  - Load equations did not adequately represent control point loading
- **Actual fleet data**
  - Actual usage flown was outside the range of design mission profile (where fatigue load cases were calculated for regression)
  - Statistically good regressions produced obviously erroneous result with actual data

Recovery Plan for Challenge 2

- **Load Equations for IAT equations**
  - Load equation development continues in parallel with IAT equation development
  - Number of loads have increased from 102 to 233
- **Regression database and IDARS feedback**
  - Regression database expanded from 800 to 13000 conditions to more adequately cover the envelope
  - IDARS identifies control points that appear in error
  - Equation goals
    - Baseline to predicted life ratio between 0.8 and 1.2
    - Weighted average standard error < 15%
    - Weighted average correlation coefficient > 0.8

Challenge 3
IAT inspection interval forecast

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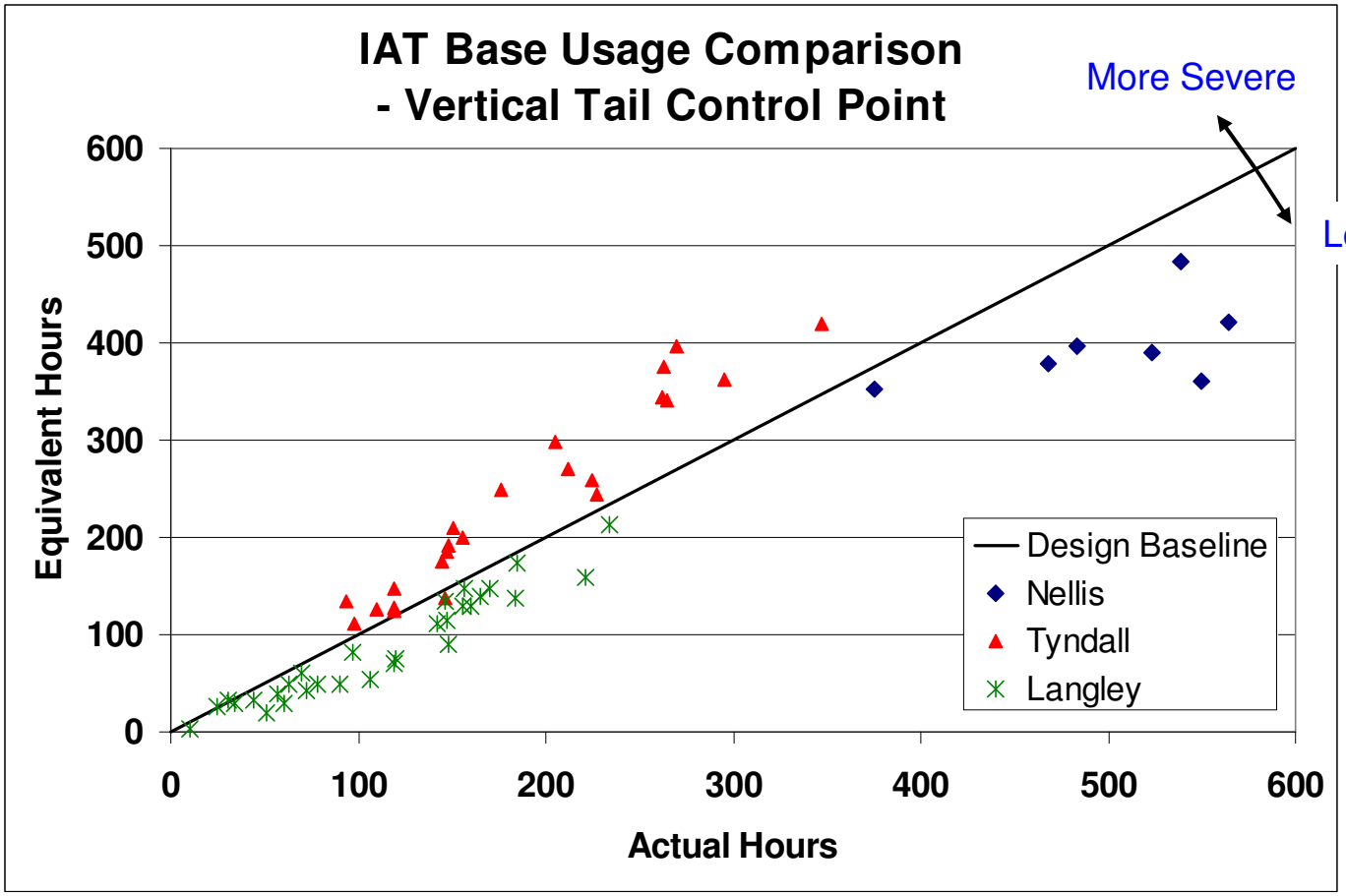
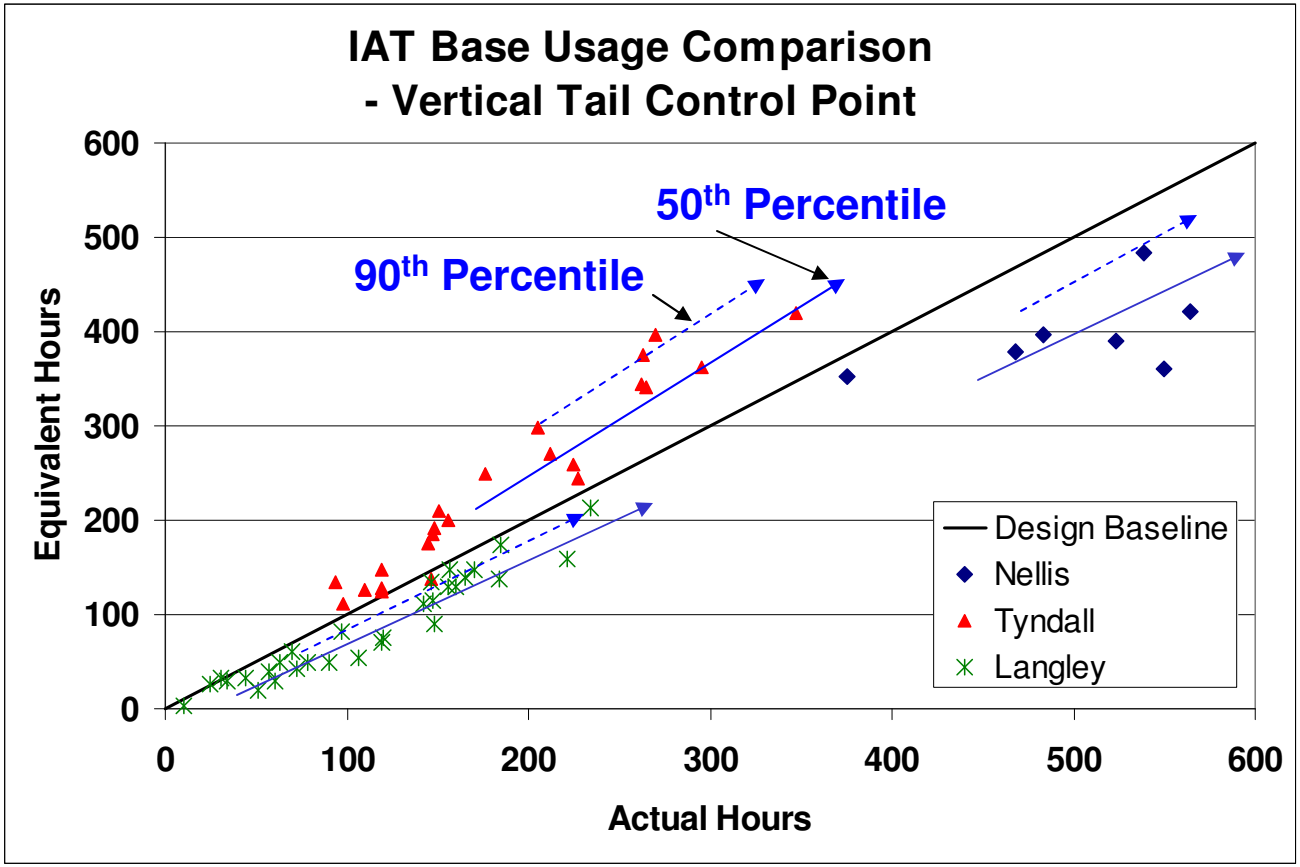
- **IAT Results Initially Forecast with Design Usage**
  - **Base variation usage observed**



Recovery Plan for Challenge 3

- **Forecast with Base Average and 90th Percentile**
  - **90th Percentile applied for < 300 hours remaining**



Structures Retrofit Plan

- **Objective:**
  - **Manage aircraft life to 8,000 hrs**
  - **Retrofit areas with a low durability and damage tolerance life discovered during the fatigue test and analysis**
- **Aircraft to be retrofitted:**
  - **EMD aircraft: 4006 – 4009**
  - **Production aircraft: 4010 – 4083**

Structures Retrofit Plan 1

Retrofit Activity	Effectivity
MWB Door - Hinge fitting replacement	4010-4021
Wing – LE hinge fitting replacement FWD Boom – Frame 2,3,4 & 5 peening FWD Boom – Frame 5 install fitting FWD Boom – Frame 3 trim web FWD Boom – Cold work frame 2 & 3 Ebay – Frame 2 & 3 cold work	4010-4040
AFT Boom – Install doublers, blends, cold work	4010-4051
FS 597 Lower Frame - cold work	4010-4083

L/ESS Report Results Summary
Key Results – NzW & Wing Root Bending

- **L/ESS-09 Report - October 2006**
  - **Includes fleet usage up through June 30, 2006**
- **Overall**
  - **Fleet usage equivalent or below baseline for positive NzW and wing root bending at all bases**
- **Tyndall**
  - **Tyndall usage higher than baseline for positive NzW and wing root bending**

L/ESS Report Results Summary

Nz and Aircraft Gross Weight (NzW)

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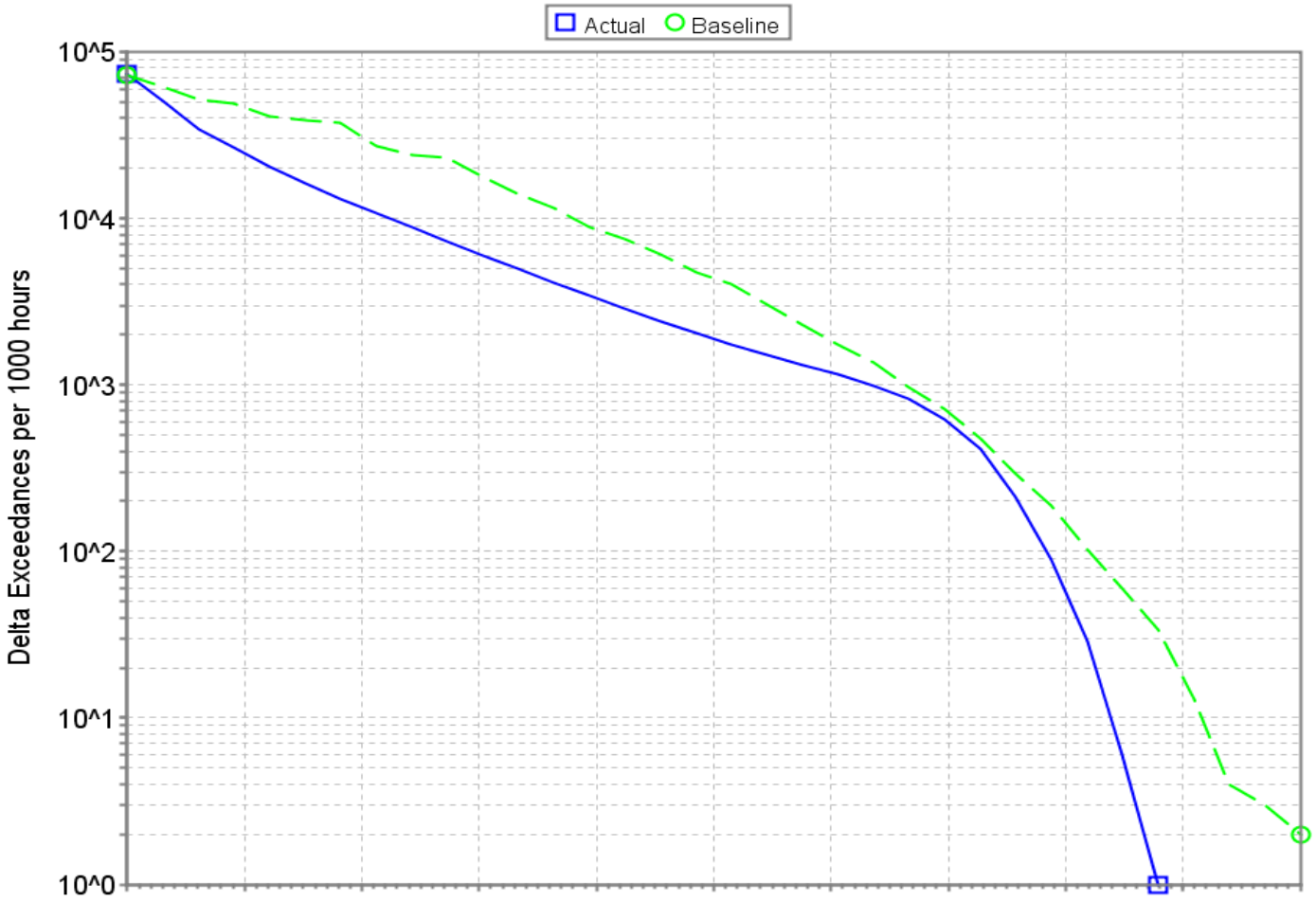
All Production Aircraft



L/ESS Report Results Summary

Nz and Aircraft Gross Weight (NzW)

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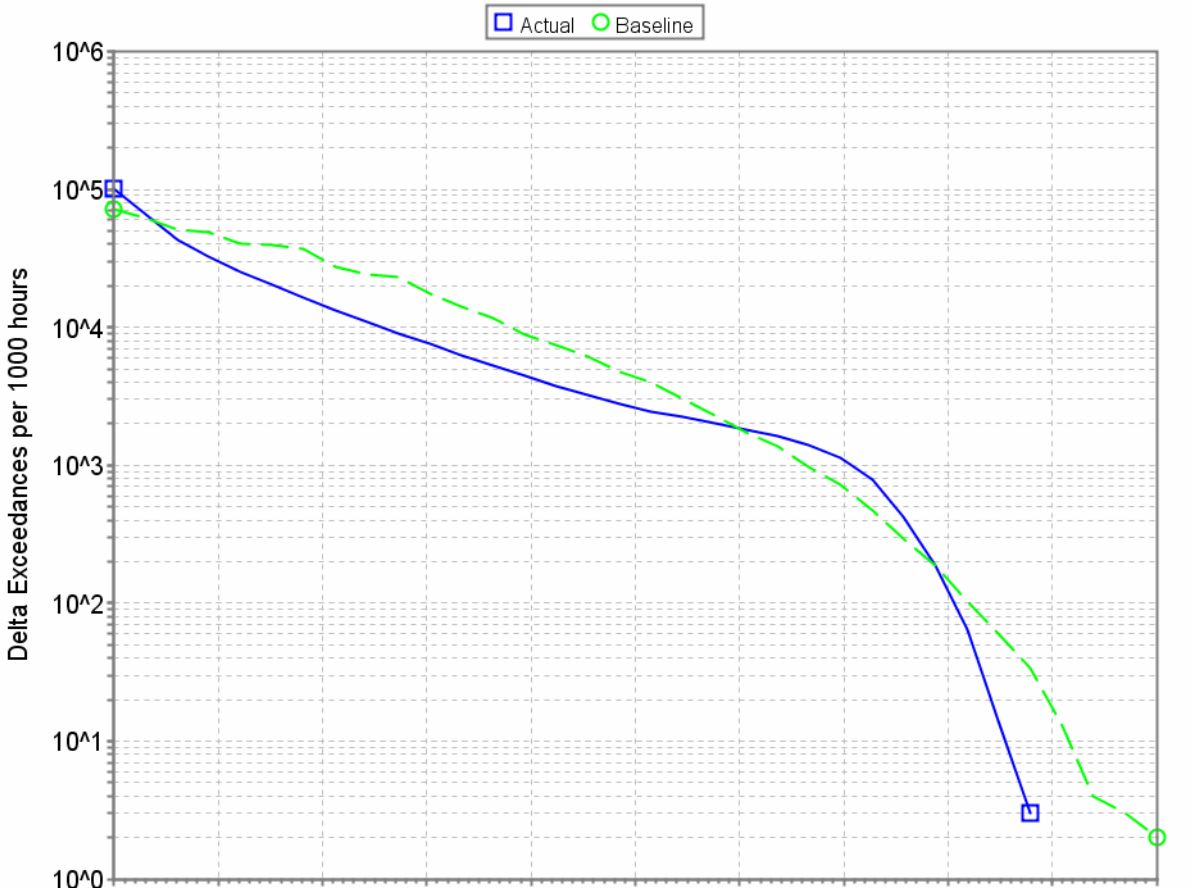
Tyndall AFB Aircraft



Product Of Nz and Aircraft Gross Weight (1000 lbs)

IAT Report Results Summary

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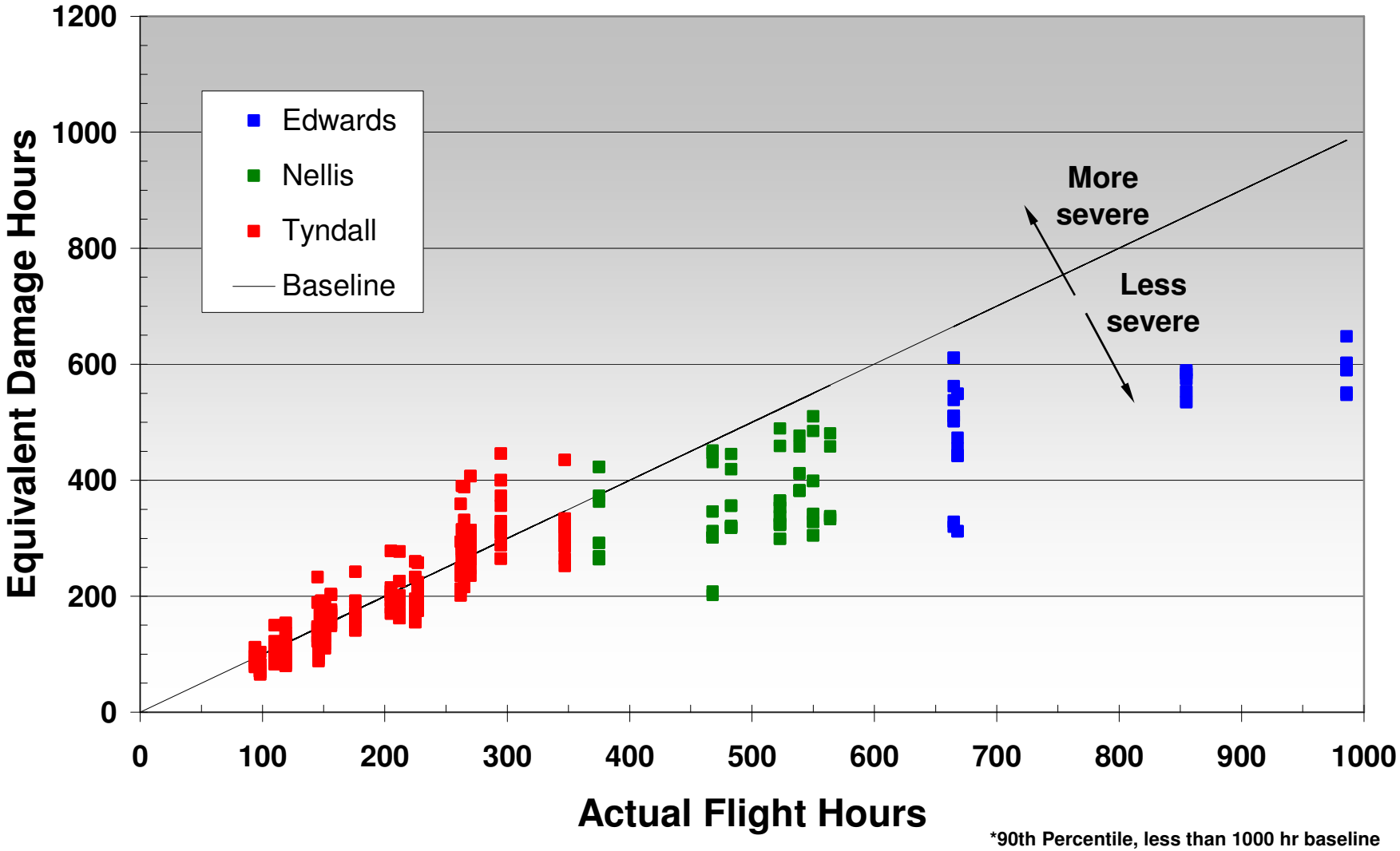
Equivalent Damage by Base



*90th Percentile, less than 1000 hr baseline

Individual Aircraft Tracking
TO Updating Process

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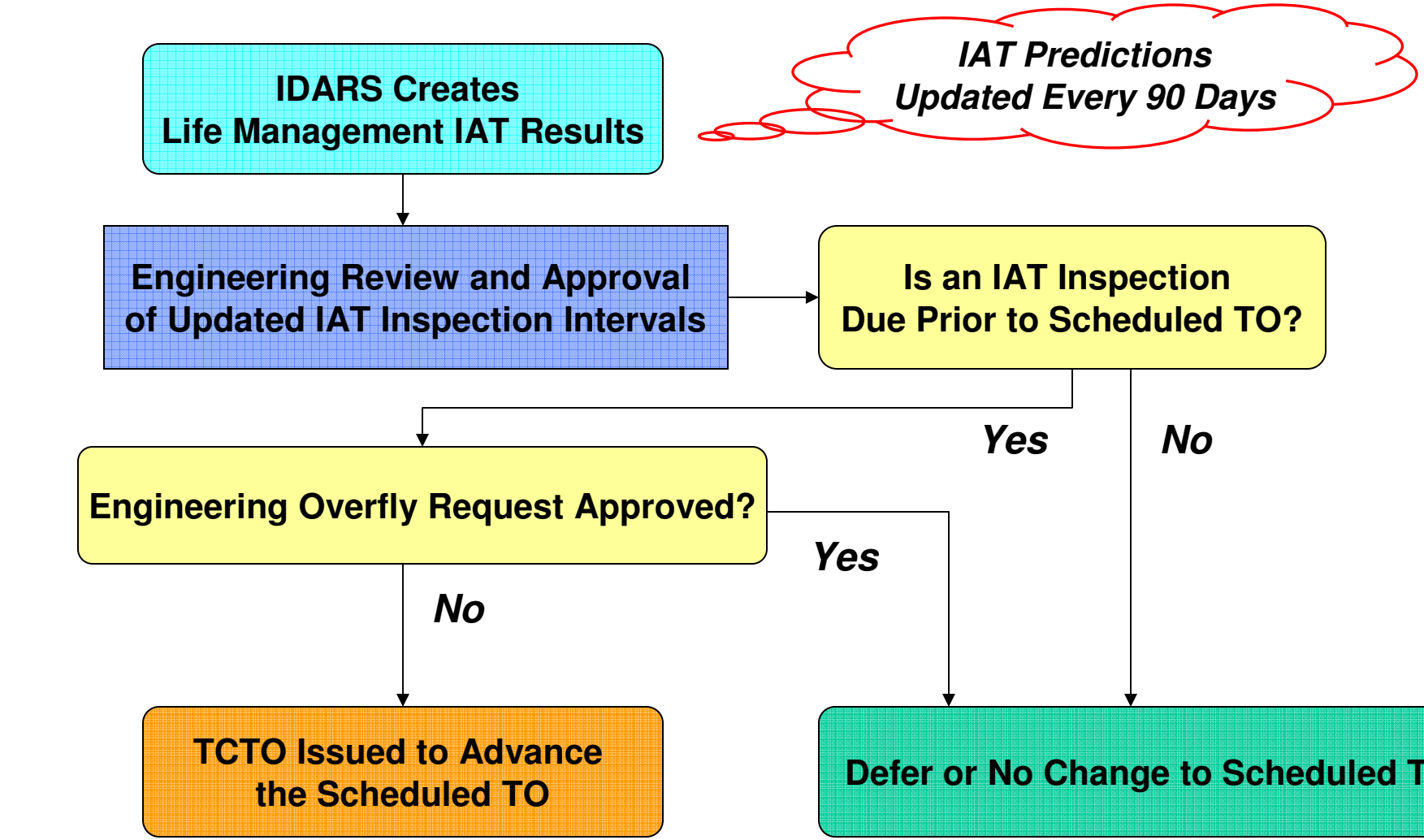

Individual Aircraft Tracking
TO Updating Process

- **Web-based access to -6 data in work**
  - **Searchable by A/C**
  - **Sort and Print Data**
  - **Prototype Developed, Demo'd**
- **If necessary, initial IAT update can be issued via update to existing paper -6 T.O.**

Force Management
Data Comparison

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Unprecedented control point tracking, improved data capture rate capabilities, and increased usage report publishing allows for higher fidelity force management decisions over legacy fighter programs

F-22	Legacy Fighter
1,408 Tracked Control Points	~60 Tracked Control Points
76.6% Operational IAT Data Recorded	56.3% Operational IAT Data Recorded
77% Operational L/ESS Time History Data Recorded	6.5% Operational L/ESS Time History Data Recorded
IAT and L/ESS Reports Released Every 90 Days	IAT and L/ESS Reports Released Once per Year

Conclusion

- ***Lessons learned / continuing actions***
  - **Development of equations depends on accurate life predictions in addition to statistical fit for IAT and L/ESS**
  - **Regression data distribution for loads equations should be uniform across parameters space**
  - **Integrated air vehicle sensors to maximize collection of data**
  - **Continue evaluating equations to fine-tune existing process**

– Communication is key to maintain structural integrity


Any Questions?