



2006 ASIP Conference

B-2 ASIP Overview

John T Bailey, Aeronautical Systems Center
Robert Tashiro, Northrop Grumman Corporation

28 November 2006



Today's Purpose

2006 ASIP Conference

- To provide a “50,000 foot view” of how the B-2 has done, is doing, and will do ASIP





Contents

2006 ASIP Conference

- **Task I - Design Information (~'81-86)**
- **Task II - Design Analyses & Development Tests (~'81-91)**
- **Task III - Full Scale Testing (~'87-95)**
- **Task IV - Force Management Data Package ('93-01)**
- **Task V - Force Management (~'98-ongoing)**



Overview

2006 ASIP Conference

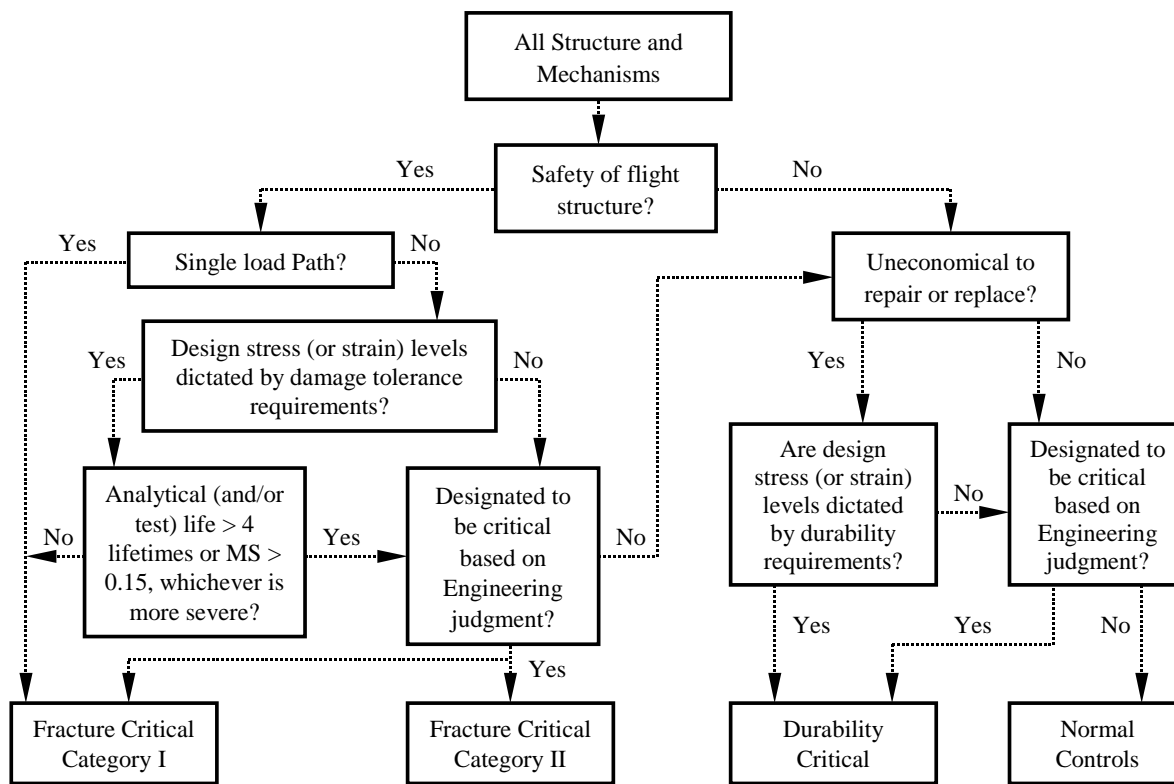
- **B-2 program initiated in 1981**
- **Only 21 aircraft**
- **ASIP based on MIL-STD-1530A**
 - First Master Plan issued one year later, 5 May 82
 - Updated annually, Rev CC - 31 Aug 05 (29 revisions)
- **Basic design criteria based on MIL-A-8860 series requirements**
- **Design service usage = 10,000 hrs**
 - 2146 flights
 - 3300 landings



Task I - Design Information: DADT Control Plan

2006 ASIP Conference

- **DADT Control Plan established to assure each critical part will meet design service life**
 - Fracture Critical Parts = Safety-of-Flight
 - Durability Critical = Uneconomical to repair/replace

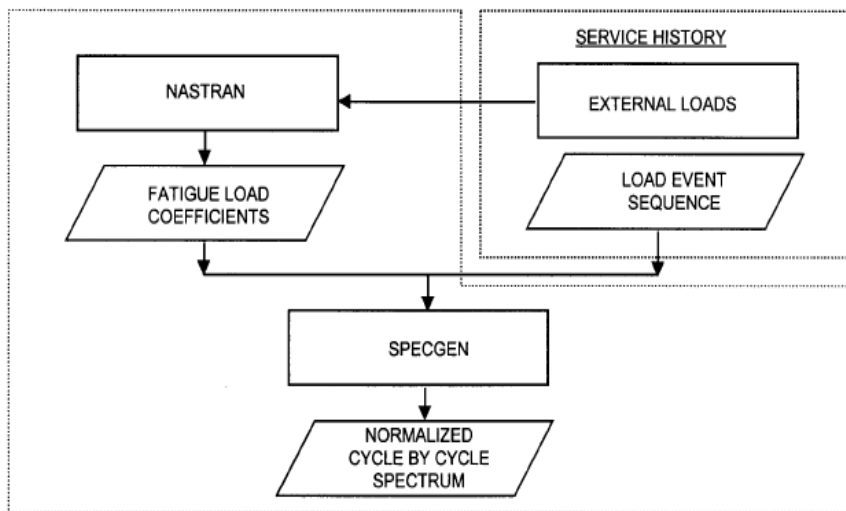




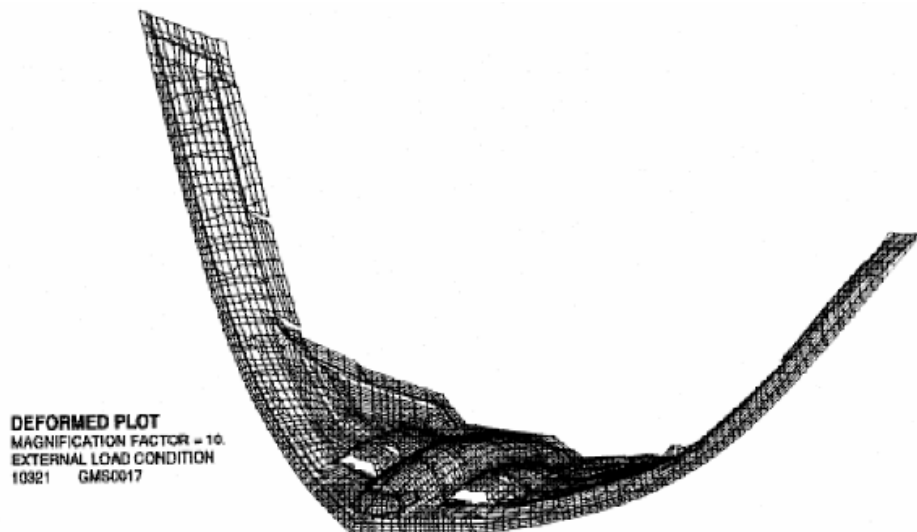
Analysis Objective

2006 ASIP Conference

- Goal was for all structure to preclude inspections throughout aircraft design life
- External loads used in combination with NASTRAN FEM to develop internal loads spectra



External Loads Methodology





Analysis Overview

2006 ASIP Conference

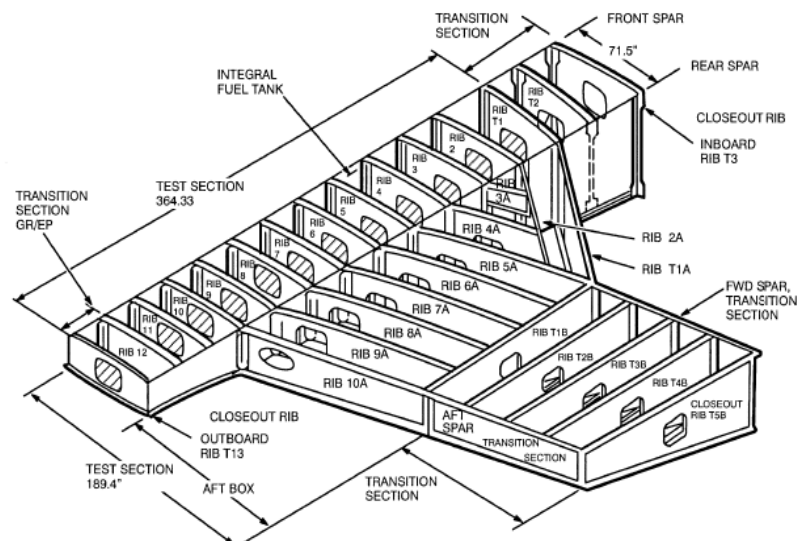
- **Loads, Stress, Dynamics, Vibroacoustics, Flutter, Weapons Effects, and DADT all performed**
- **Durability analysis**
 - Metallic parts were analyzed using Local Strain-Based crack initiation
 - Composite parts were analyzed using Damage Threshold Strain Limits or Residual Strength
- **Damage Tolerance analysis**
 - Metallic parts were analyzed with crack growth model that accounted for cycle-by-cycle load sequence effects
 - Composite parts were analyzed by comparing allowable strains with applied design strains



Tests Overview

2006 ASIP Conference

- **Purpose:** To assist in the evaluation and validation of design concepts
- **Significant tests included...**
 - Leading and trailing edge structure
 - 30' section of the outboard wing
 - Windshield frame joints
 - Critical airframe splices
 - Forward wing carry-thru box
 - Landing gear drop
 - Armament store ejection
 - Several flutter wind tunnel
 - Nuclear thermal effects



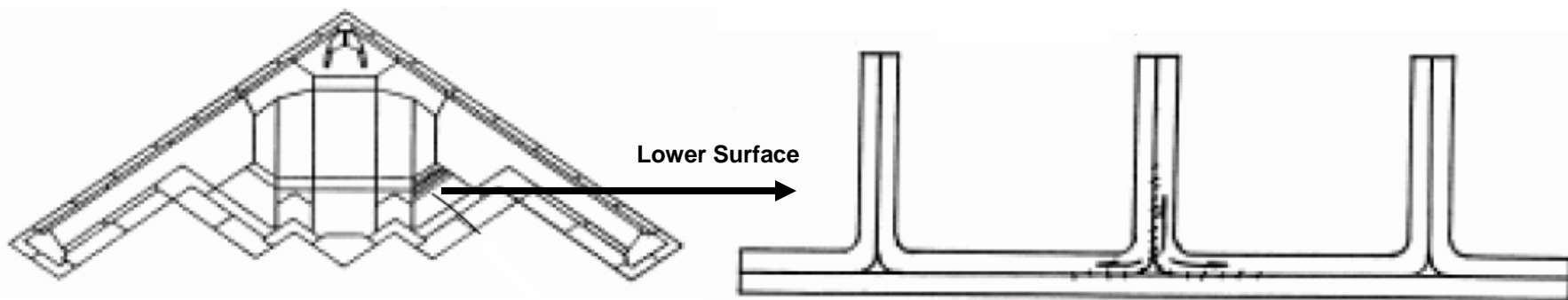


Task III - Full Scale Testing:

Static Test

2006 ASIP Conference

- **Purpose: To verify no material yielding at limit load and no structural failure at 150% of limit load**
- **93 total load conditions applied -- very successful**
- **Single test-to-failure conducted on 16 Dec 92**
 - 156% DLL needed to verify strength for an increase in weight
 - Initial failure at 161% DLL -- took 15 minutes for failure to progress thru entire structure



- **Article was repaired and given to USAF Museum**



Task III - Full Scale Testing: **Durability Test**

2006 ASIP Conference

- **Purpose:**
 - To demonstrate economic life is equal to or greater than the design service life
 - To identify critical areas not previously identified
- **Test spectrum had 2.25 million cycles per lifetime**
- **Successful test to 2 lifetimes**
 - Relatively minor deficiencies found -- 30 identified, primarily in fasteners, clips, shear ties, and brackets
 - Only 9 identified during the 11-month teardown inspection
- **Economic life greater than design**



Overview

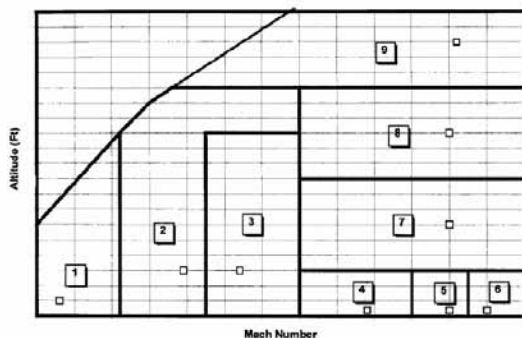
2006 ASIP Conference

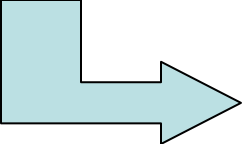
- **Design Analyses and SSOR updated to include test results, increased weight, and updated spectrum**
- **Loads/Environment Spectra Survey (L/ESS)**
 - Purpose: To determine when a significant change in aircraft usage has occurred and to provide an updated spectrum
 - Originally proposed but then deleted in 1993 as a cost-savings due to low risk because of the B-2's unique IAT program
 - Thus no L/ESS instrumentation
- **Individual Aircraft Tracking (IAT)**
 - Purpose: To adjust maintenance intervals for individual aircraft based on actual usage
 - B-2 IAT program was an extension of the analysis and spectrum generation methods used for design and test
 - No dedicated IAT instrumentation -- all necessary data collected with flight data recorder
 - Data can be used to determine L/ESS for 100% of fleet

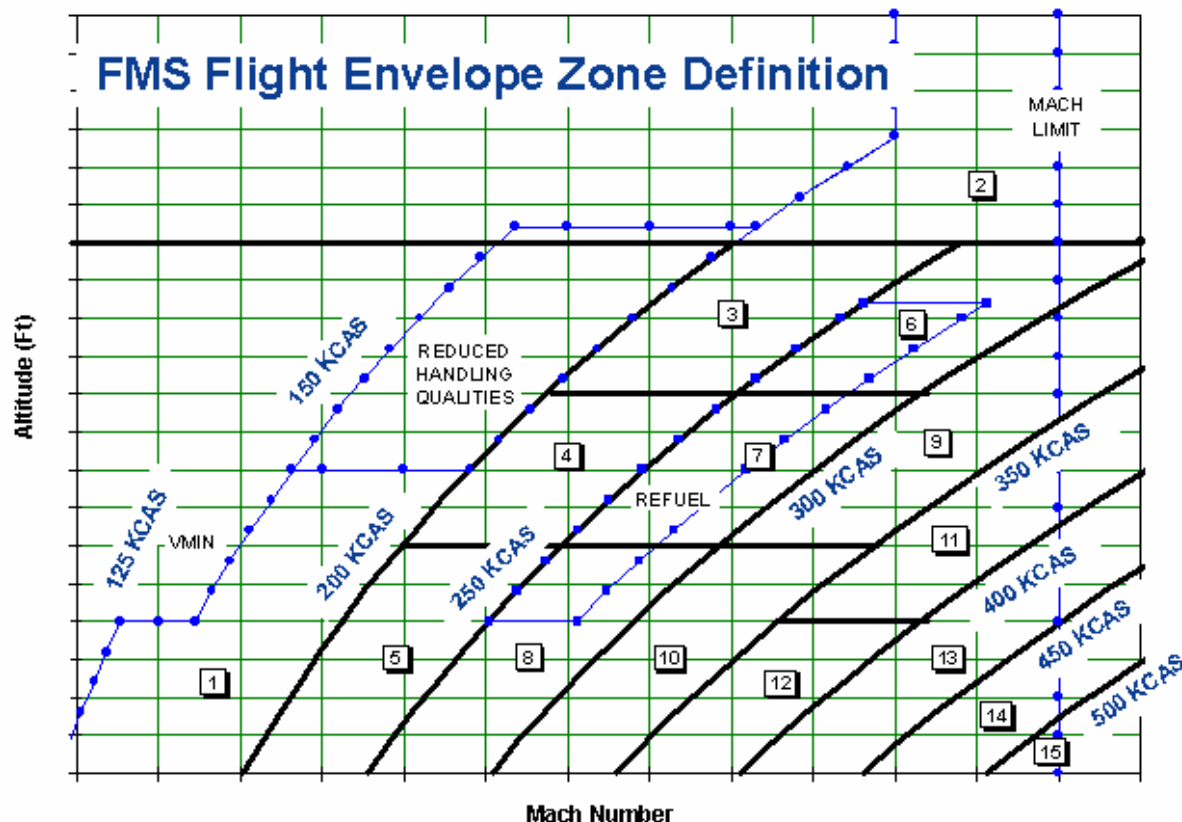


Task IV - Force Management Data Package: IAT Development

2006 ASIP Conference




 Re-definition in 1999



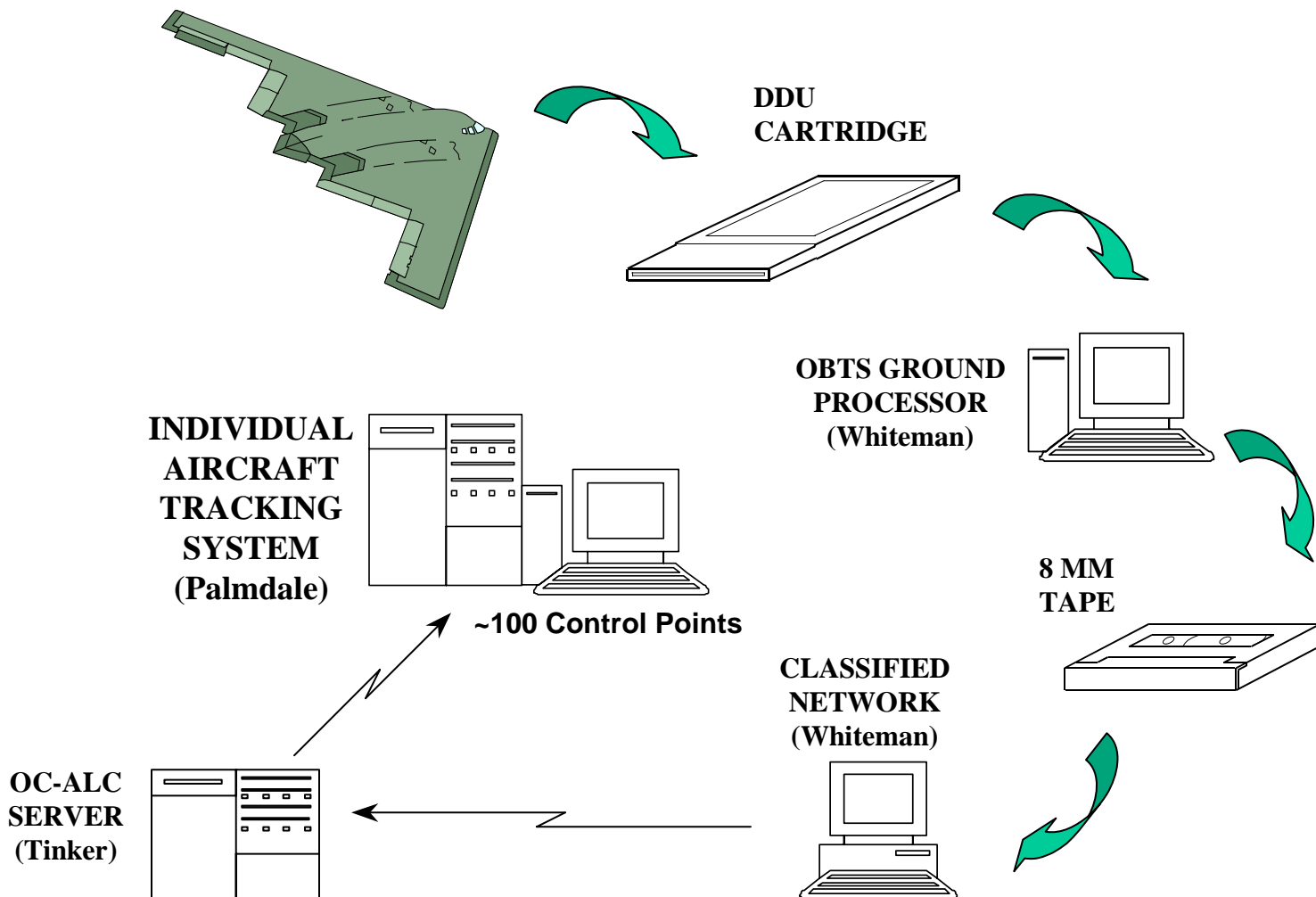
- External load conditions represented by zones defined in the flight envelope
- Min/max loads known for min/max operating weights -- actual loads interpolated from “point-in-the-sky”



Task IV - Force Management Data Package:

IAT Data Transfer

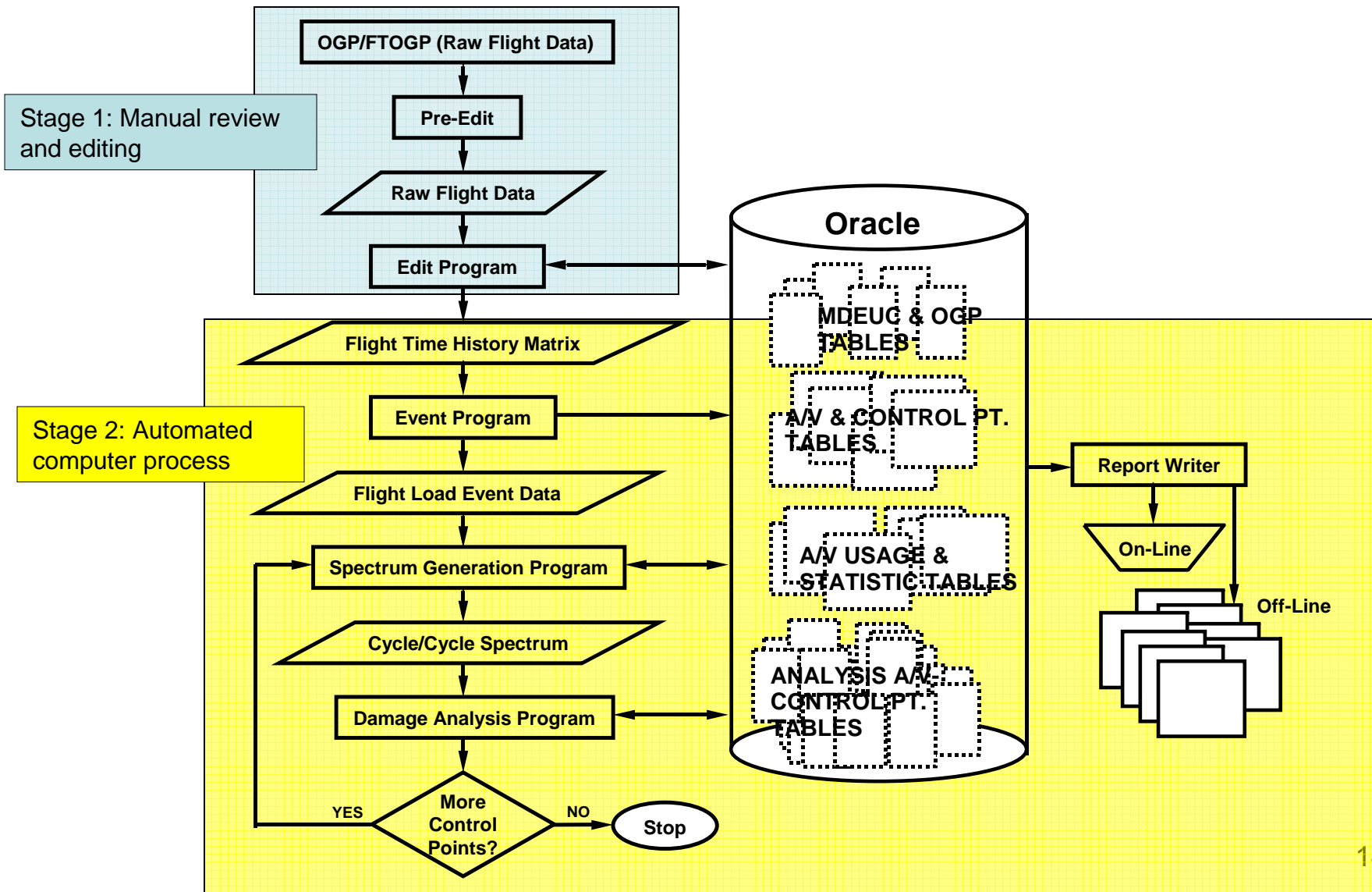
2006 ASIP Conference





Task IV - Force Management Data Package: IAT Data Processing

2006 ASIP Conference



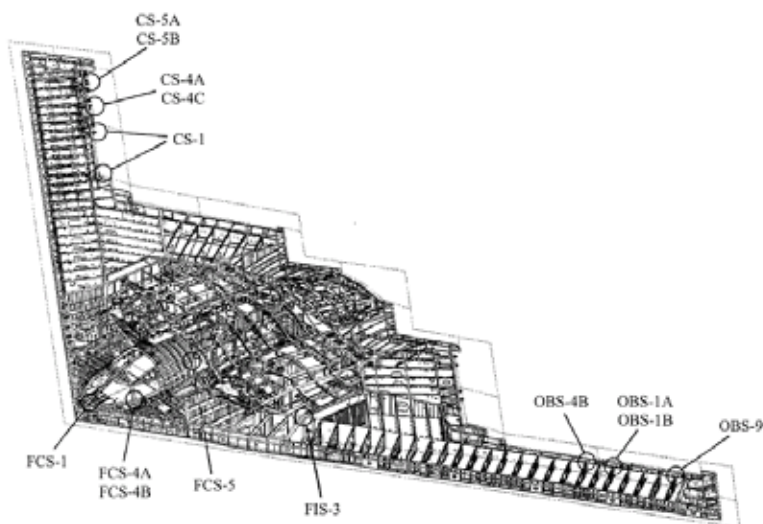


Task IV - Force Management Data Package:

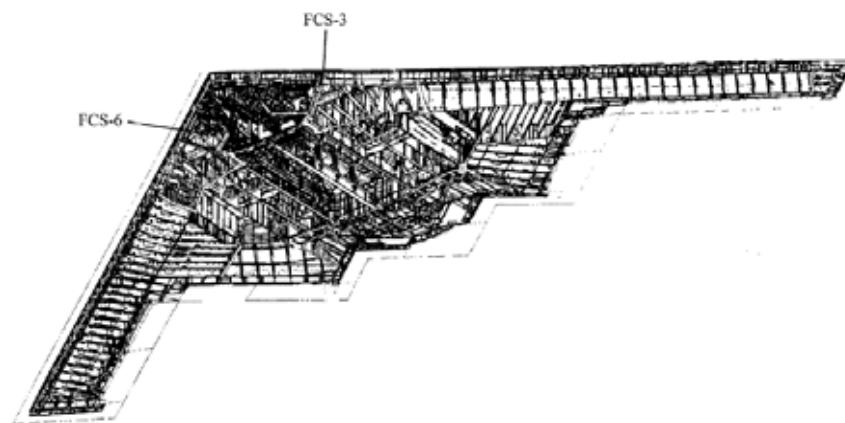
FSMP

2006 ASIP Conference

- **Force Structural Maintenance Plan (FSMP) defines structural inspection intervals and procedures for structure that does not meet the design service life**
- **Per design usage, only 16 parts require inspection**
 - No modifications programmed
- **First failure likely to be the rudder attachment points**



Upper Surface FSMP Parts

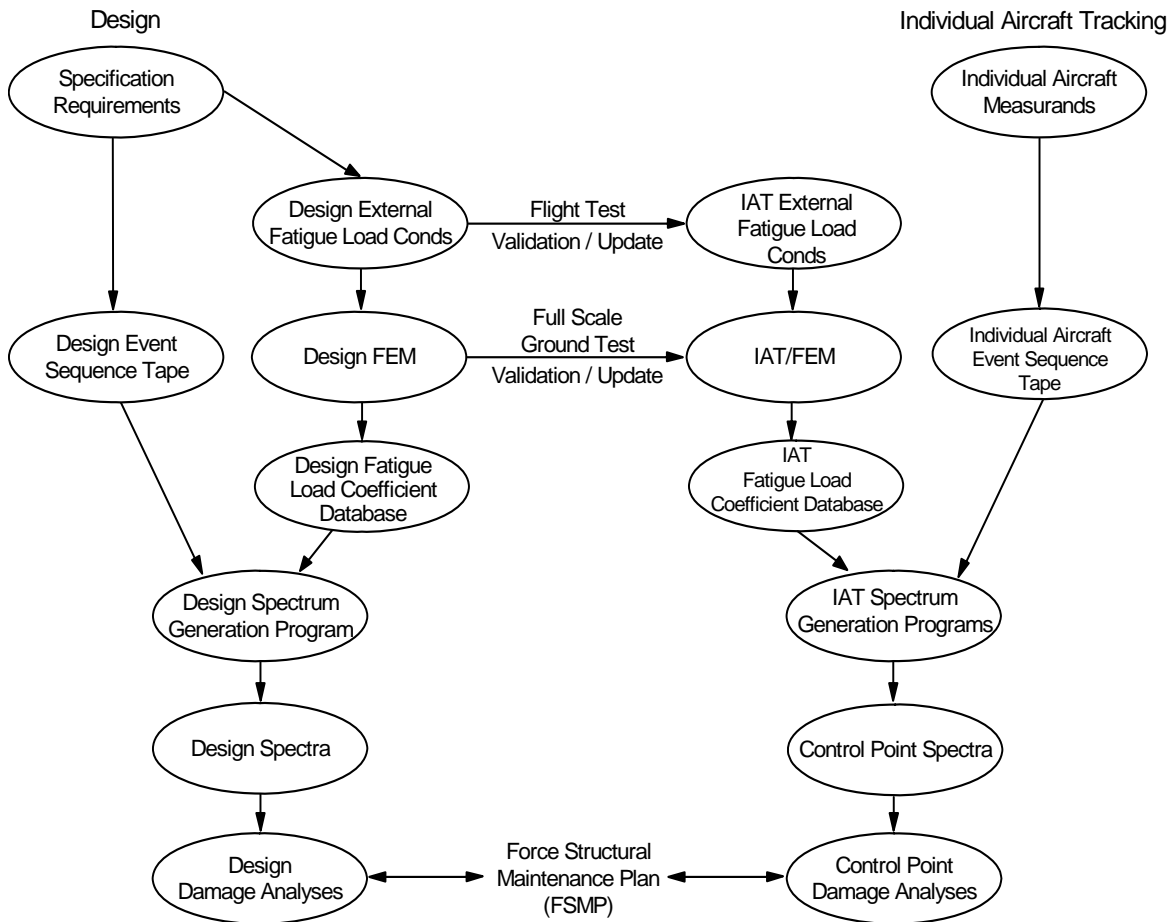


Lower Surface FSMP Parts



Task IV - Force Management Data Package: FMS Summary

2006 ASIP Conference



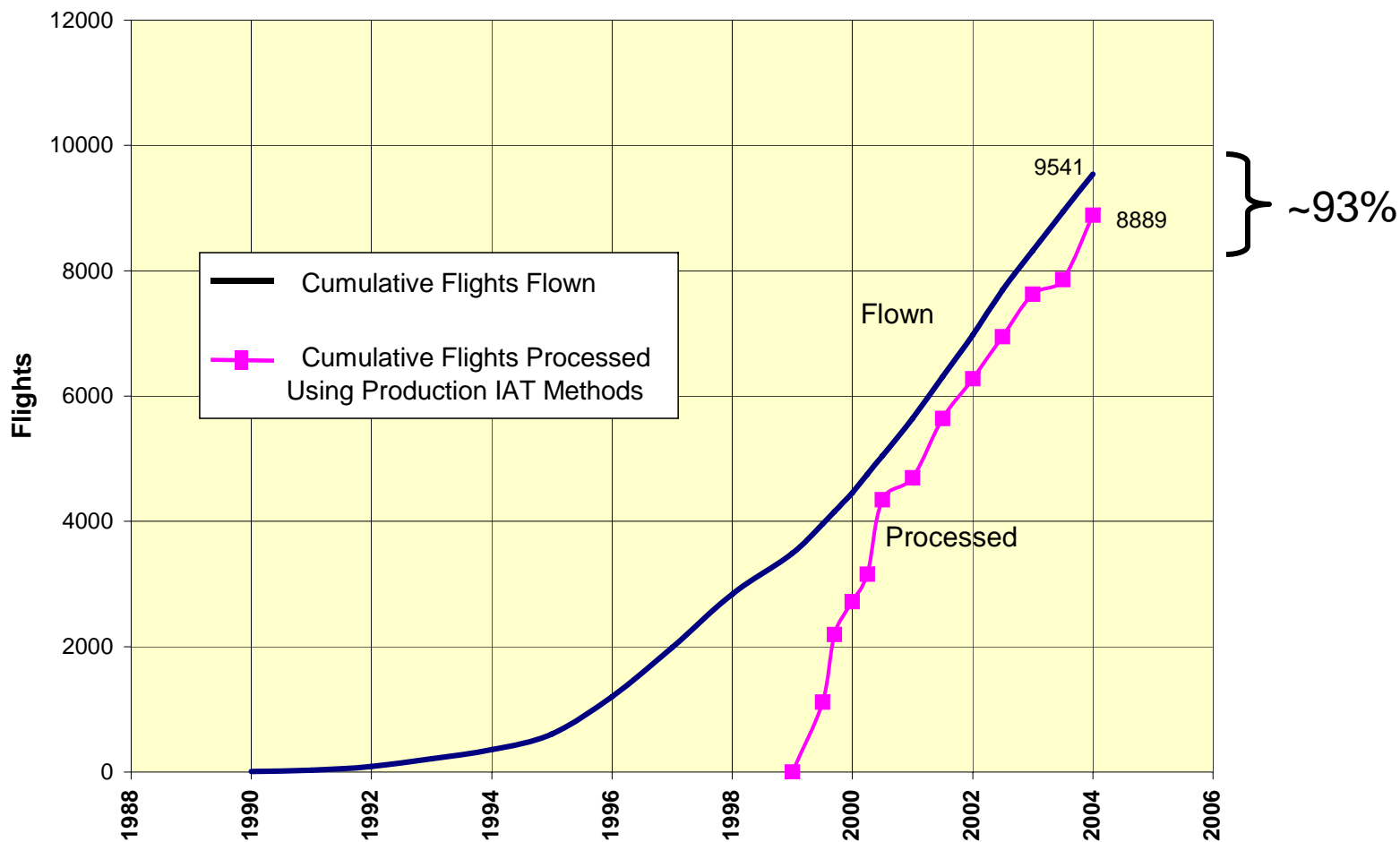
Design, test, and IAT methodology is same



IAT Results

2006 ASIP Conference

- IAT Report generated twice a year

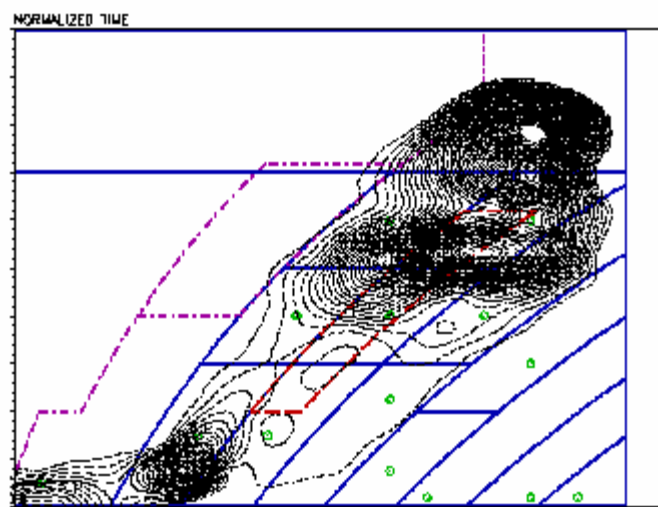
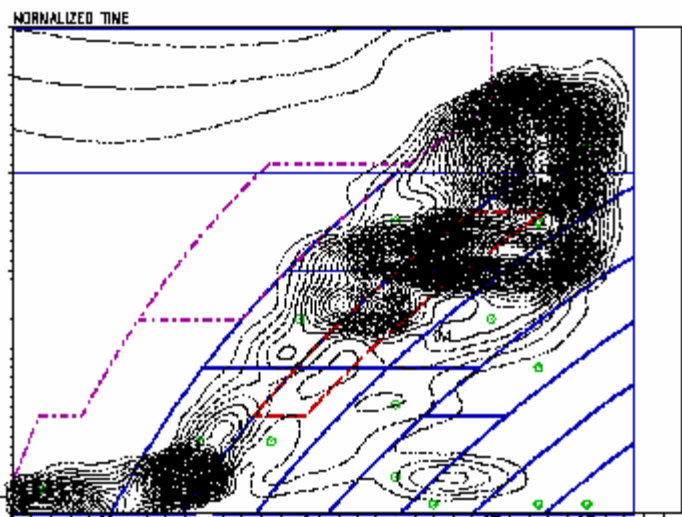




B-2 Usage Trends

2006 ASIP Conference

- **Data available for real-time usage assessments**
- **Actual usage changes**
 - Nuclear to nuclear/conventional
 - Longer missions at cruise
 - Significantly reduced low altitude, high speed flight hours
 - Increased touch and go rates (4X)
 - Increased number of throttle changes





SLEP

2006 ASIP Conference

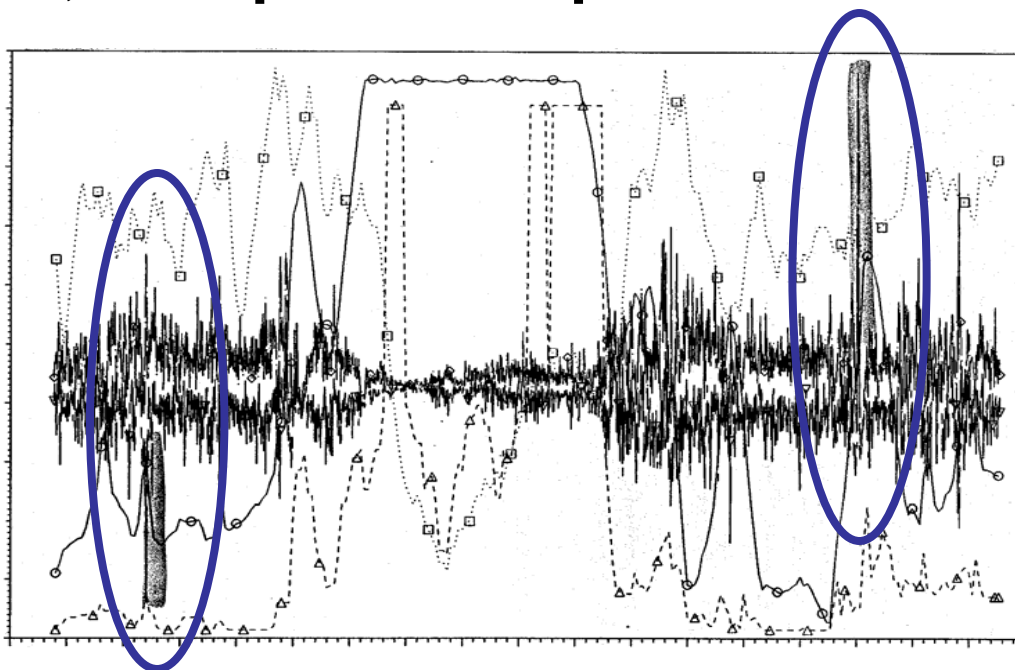
- **In 2004, B-2 was requested for a new service life projection**
- **Top-level assessment of successful durability test and few FSMP items recommended 20,000 flight hours (2X design life)**
- **Service Life Extension Program (SLEP) commenced this year to determine new FSMP requirements**
 - Phase 1: Generate updated usage spectrum
 - Phase 2: Verify methodology with coupon-level testing
 - Phase 3: Update DADT analyses and FSMP



Over-G Evaluations

2006 ASIP Conference

- Creating a software program to automatically evaluate over-G occurrences and recommend inspection locations
- Provides more thorough review, more specific locations, and quicker responses to the warfighter





Task V - Force Management Execution: **Other ASIP Activities**

2006 ASIP Conference

- **Force Management System is being transferred entirely to OC-ALC**
- **Aft deck cracking and redesign**
 - IAT control points planned for redesigned deck
 - Actual usage spectrum developed for root cause analysis



Summary

2006 ASIP Conference

- **B-2 has employed a robust ASIP from Day 1**
- **Unique IAT program collects L/ESS data without instrumentation**
- **Successful test program and change in usage has allowed for an increased goal for service life**

Disciplined ASIP has kept, is keeping, and will keep the B-2 flight-worthy for years to come