

# ASIP on the U-2

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*560<sup>th</sup> Aircraft Sustainment Group (C2ISR)*



**Tailoring of an Aircraft Structural Integrity Program for High Demand, Low Density Pre-ASIP Aircraft**

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LM Aero-Palmdale***

**U.S. AIR FORCE**

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# U-2S Mission Configurations



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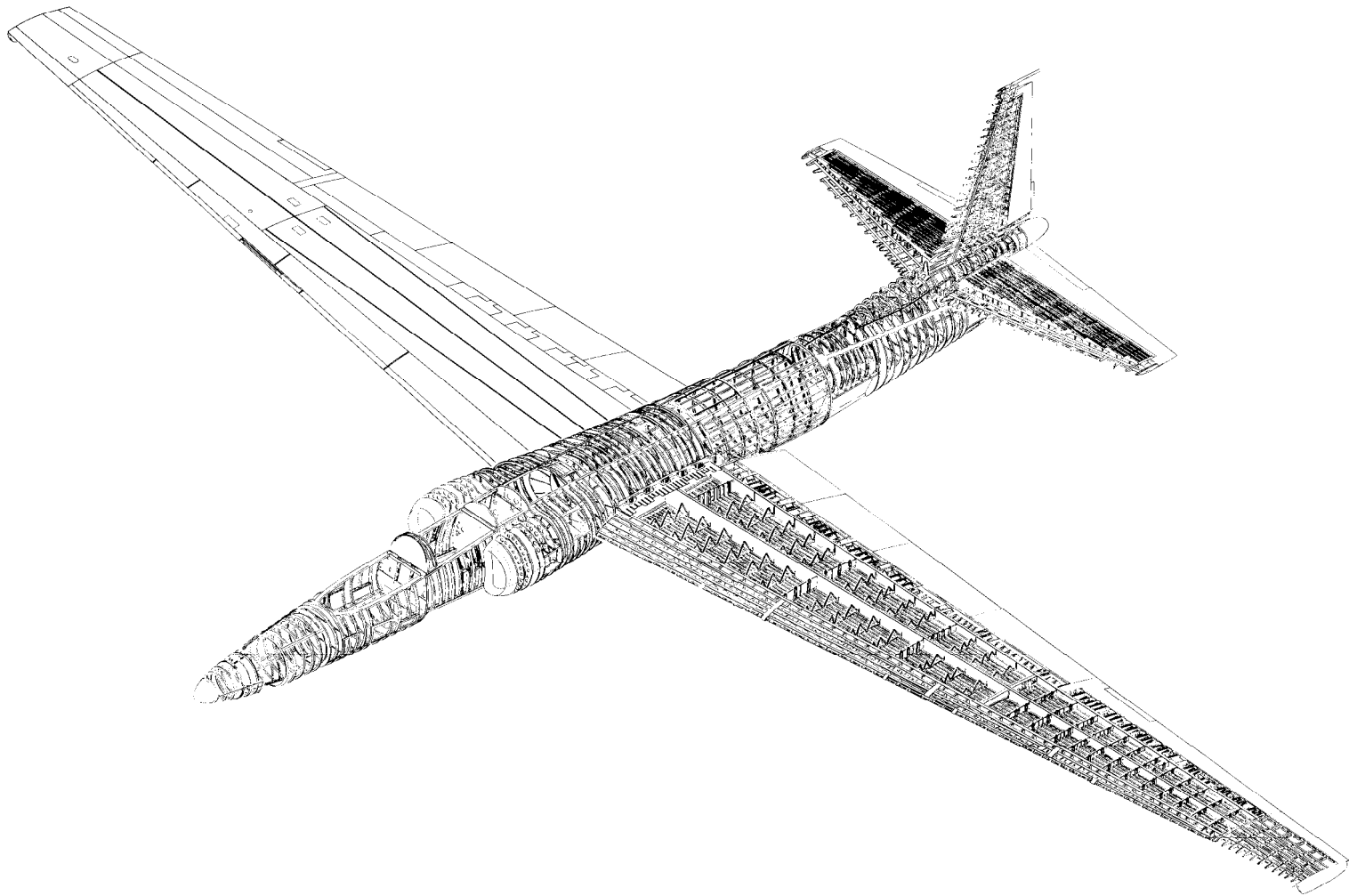


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# U-2S Construction



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# U-2 History and Development



*560<sup>th</sup> Aircraft Sustainment Group (C2ISR)*

- **U-2R First Flight August, 1967**
- **USAF procured from another agency, with no requirement or provision for ASIP**
- **Service Life was not initially an issue**
  - No fatigue test or analysis
  - Rigorous IRAN program
- **Initial build was 12 airframes plus static test**
  - 6 USAF
  - 6 Agency
- **Lessons learned from U-2C experience incorporated into R-Model design**



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# U-2 History and Development



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- **Initial fatigue analysis accomplished 1976**
- **Restart TR-1A/U-2R production in 1979**
  - 36 airframes, same configuration as existing U-2R
  - 3 TR-1B/U-2RT trainer aircraft
  - Airframe life analysis accomplished as part of restart effort
    - Greater than 20,000 hours (with 2 exceptions)
    - 7 areas of concern identified for PDM inspection on airframes older than 20,000 hours
- **Re-engined and converted to U-2S beginning 1993**
  - F118-GE-101 replaced J75P13B
  - New engine mount structure
  - Added AMAD and Secondary Power Equipment



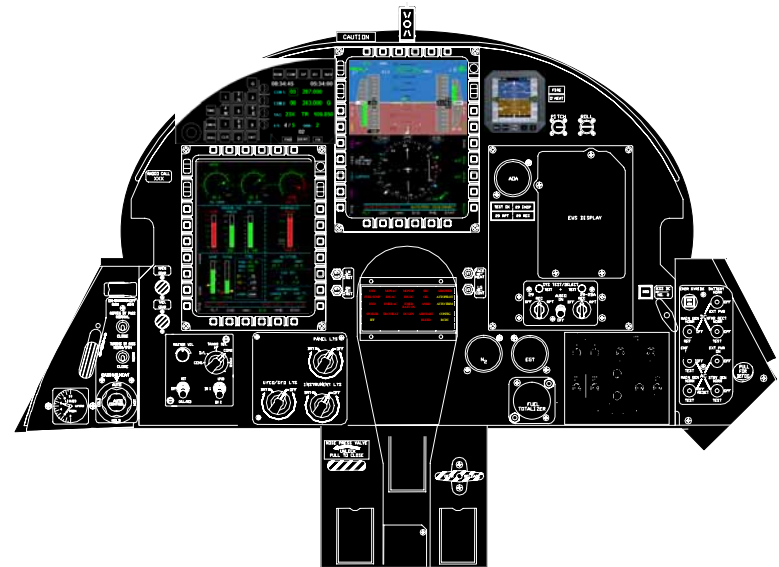
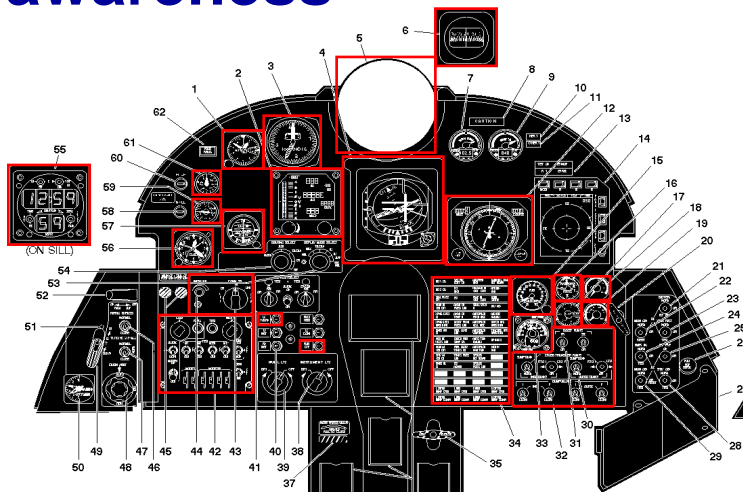
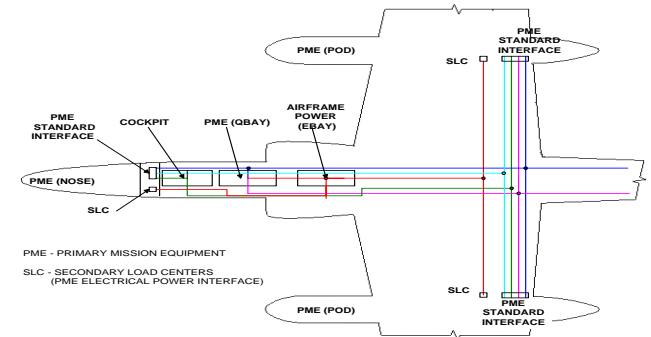
# U-2 History and Development



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- **Block 10 Upgrade beginning in 1997**
  - Rewire to reduce EMI
  - New power distribution system
  - “Group B” provisions
  - Life re-addressed
- **Block 20 Upgrade beginning in 2000**
  - Reduce pilot workload and increase situational awareness





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# U-2 Meets ASIP



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- **Re-engine, planned Block 10 and Block 20 Mods significant investment in the U-2 Airframe**
- **U-2 Specific sensors upgrades planned**
- **1968 build airframes approaching 20,000 Flight Hours**
- **Need to insure return on investment**
- **ASC/EN Report on concerns for aging aircraft**
- **WR-ALC/LX directs a tailored ASIP for the U-2**





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# U-2 ASIP Plan Development



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- **Challenges in Developing U-2 ASIP**
  - **No Loads Survey**
  - **No initial fatigue test**
  - **No instrumented aircraft**
  - **No plans or provisions for ASIP in design or documentation**
  - **Service history incomplete prior to late 1980s**
    - **Significant events not always documented**
    - **Paper only, not easily searchable**
    - **Payload, mission type, etc not always noted**
  - **Widely varying payload configurations, fuel loads, mission profiles and mission mixes**





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# U-2 ASIP Plan Development



*560<sup>th</sup> Aircraft Sustainment Group (C2ISR)*

- **ASIP Master Plan developed jointly**
  - WR-ALC/LX - Mr. Mangrum
  - ASC/EN - Dr Jack Lincoln, Dr Hsing Yeh, and others
  - LM Aero (OEM) Mr. Priestley, Mr. Lenvik and others
  
- **Based on review of available information**
  - Current activities (1998 Service Life Study)
  - ASIP requirements
  - Previous History (Four 20,000 flight hour aircraft as “Lead the Fleet” aircraft)
  - Projected program life and ops tempo



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# U-2 ASIP Plan Development



*560<sup>th</sup> Aircraft Sustainment Group (C2ISR)*

- **Three phased approach**
  - **Complete 1998 Service Life Study with enhancements**
    - **Include empennage**
    - **Include limited fracture analysis**
  - **Accomplish NDI of “Hot Spots” on two 20,000 flight hour aircraft at PDM**
  - **Monitor aircraft performance**
    - **In service failures**
    - **Mission profiles and mixes**
    - **Compare to ASIP baseline and address differences**
    - **Publish in an annual update to the ASIP Master Plan**



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# U-2 Structural Evaluation Plan



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- **1998 Service Life Evaluation**
  - Reassess life of the airframe
  - Addressed Wing and Fuselage only
  - Used measured stresses and correlated loads
    - Strain Gages located at previously identified (1979 Life Update) “critical areas”
    - Both ground and flight data
- **Additional Tasks for ASIP**
  - Empennage Fatigue Analysis
  - Wing and Empennage Fracture Analysis



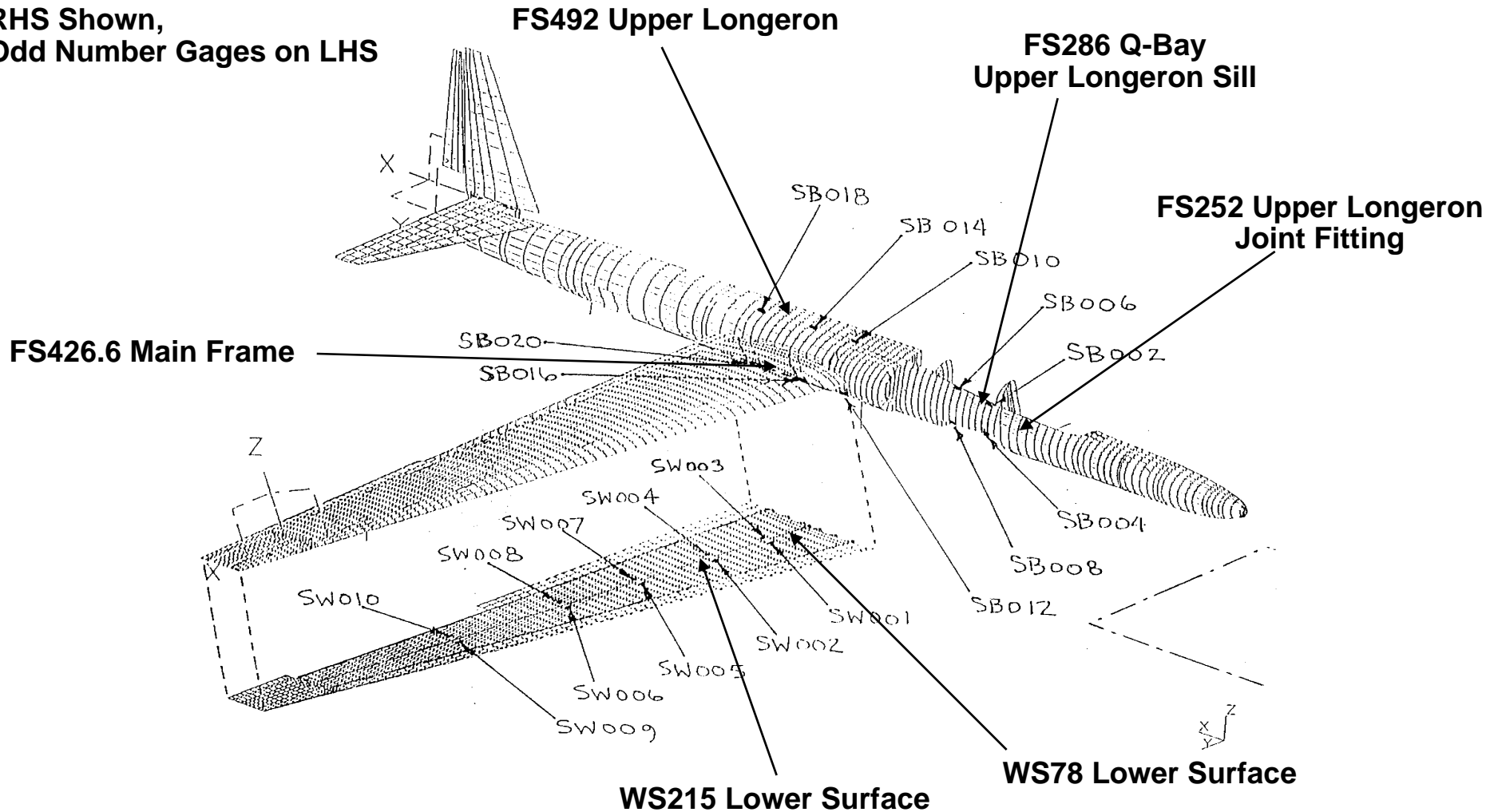
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# 1998 Service Life Study Instrumentation



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RHS Shown,  
Odd Number Gages on LHS



Strain gages to determine stresses at critical locations from 1979 fatigue Analysis

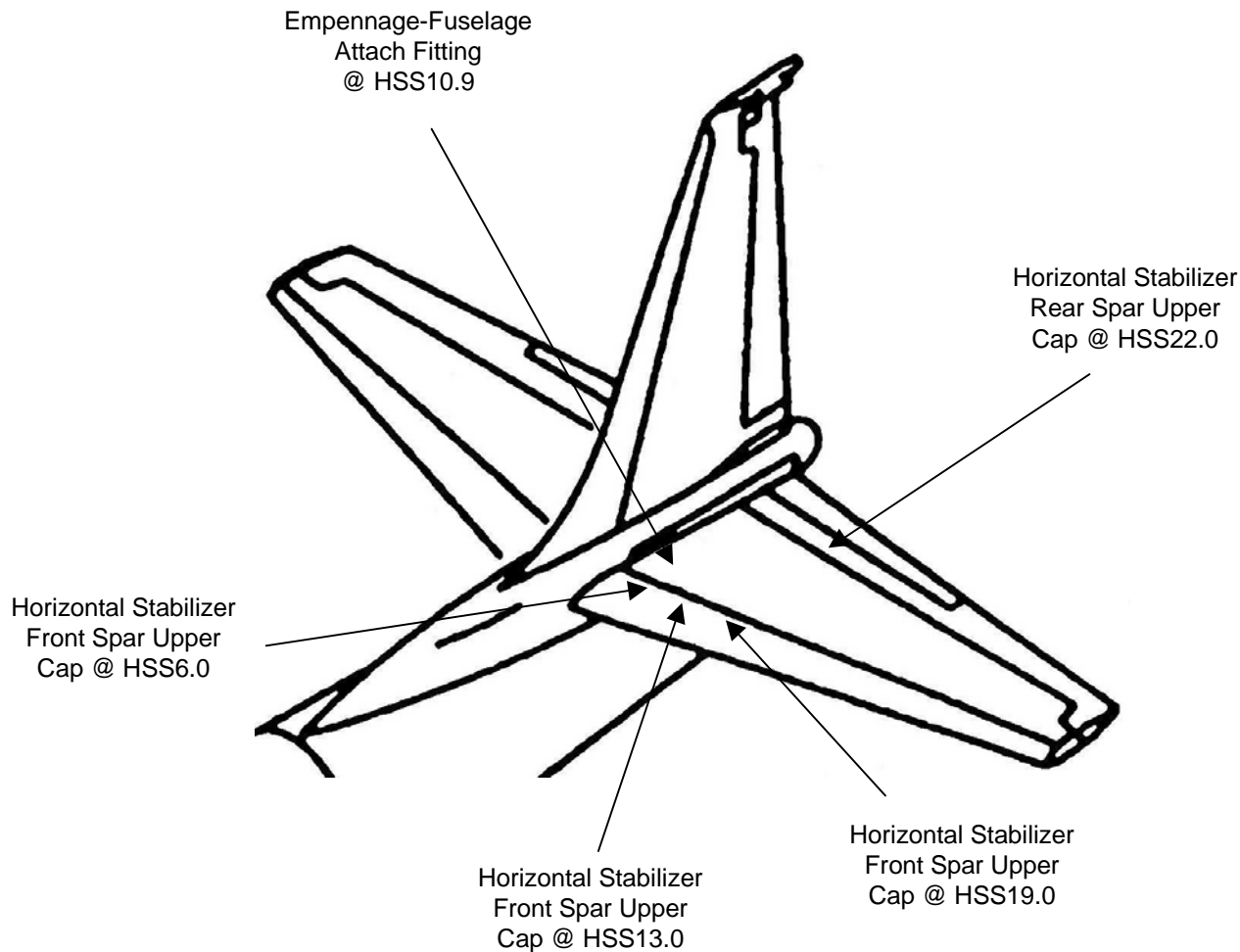


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# 1998 Empennage Critical Areas of Concern



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# 1998 Service Life Study Results



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	<u>SP4445</u>	<u>SP5165</u>	<u>SP7952/SP8206</u>
	Fatigue Analysis Feb. 1976	Fatigue Analysis 1979 Update	1998 Airframe Service Life Pgm.
• FS 252 Upper Long. Ftg.	78,750	>20,000	>100,000
• FS 286 Upper Long. Skin	10,138	10,564	>100,000
• FS 492 Upper Long. Skin	22,156	18,618	>100,000
• FS 426.6 Main Frame	27,988	20,839	>100,000
• WS 78 Wing Lower Skin	31,500	20,250	75,000
• HS 18.5 Upper Skin	91,928	>20,000	>100,000
• Empennage Ftg.	10,450	>20,000	>100,000
•		(Ftg. beefed up)	



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# U-2 Service Life Study Conclusions



*560<sup>th</sup> Aircraft Sustainment Group (C2ISR)*

- **Service Life Study showed**
  - Initial fatigue analysis (1976 and 1979) were very conservative
  - Fatigue Life
    - Lower wing skin @ WS 78, has life of 75,000 flight hours using current mission mixes and payloads
    - All other critical areas >100,000 flight hours
  - Crack Growth
    - Lower wing surface @ WS40 & 59 critical crack length reached at 12,000 flight hours (.050” initial flaw size)
    - All other critical areas >16,000 flight hours





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# U-2 ASIP Implementation



*560<sup>th</sup> Aircraft Sustainment Group (C2ISR)*

- **Completed ASIP Tasks**
  - Service Life Study
  - Detailed inspections of fatigue critical areas on two 20,000 hr+ PDM aircraft
- **Ongoing ASIP Tasks**
  - Review of structural failure and corrosion data from
    - Form 107 requests for repair
    - Periodic Inspection Form 131 reviews
    - PDM Squawks
  - Review and comparison of aircraft usage to ASIP Mission Mixes
  - Annual update of ASIP Master Plan





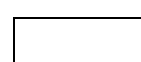

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# U-2 ASIP Implementation



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TASK I	TASK II	TASK III	TASK IV	TASK V
<b>DESIGN INFORMATION</b>	<b>DESIGN AND DEVELOPMENT TESTS</b>	<b>FULL SCALE TESTING</b>	<b>FORCE MANAGEMENT DATA</b>	<b>FORCE MANAGEMENT</b>
<i>ASIP Master Plan</i>	<i>Materials and Joint Allowables</i>	<i>Static Tests</i>	<i>Final Analyses</i>	Loads Environment
Structural Design Criteria	<i>Loads Analysis</i>	Durability Tests	<i>Strength Summary</i>	Spectra Survey
Damage Tolerance and Durability Control	Design Service Loads Spectra	Damage Tolerance Tests	Force Structural Maintenance Plan	Individual Aircraft Tracking Data
<i>Selection of Materials, Processed, and Joining Methods</i>	Design Chemical and Thermal Environment Spectra	Flight and Ground Operations Tests	Loads Environment Spectra Survey	Individual Airplane Maintenance Times
Design Service Goal and Design Usage	<i>Stress Analysis</i>	Aeroacoustic Tests	Individual Aircraft Tracking Program	<i>Structural Maintenance Records</i>
<i>Mass Properties</i>	Damage Tolerance Anal.	<i>Flight Vibration Tests</i>		<i>Weight and Balance Records</i>
	Durability Analysis	<i>Flutter Tests</i>		
	<i>Aeroacoustics Analysis</i>	<i>Interpretation and Evaluation of Test Results</i>		
	<i>Vibration Analysis</i>	<i>Weight and Balance Testing</i>		
	<i>Flutter Analysis</i>			
	Effects Analysis Nuclear & Non-Nuclear Weapons			
	Design Development Tests			
	Mass Properties Analysis			

	U-2 Compliant
	U-2 Partially Compliant
	U-2 Non-Compliant
	Not Applicable



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# U-2 ASIP Lessons Learned



*560<sup>th</sup> Aircraft Sustainment Group (C2ISR)*

- **Tailoring of ASIP requirements leads to a cost effective, non-intrusive program**
- **Current program status, performance history, and available information establish tailoring requirements and program goals**
- **Annual updates of ASIP documentation provide valuable reference information and perspective**
- **Lead the Fleet experience is invaluable**



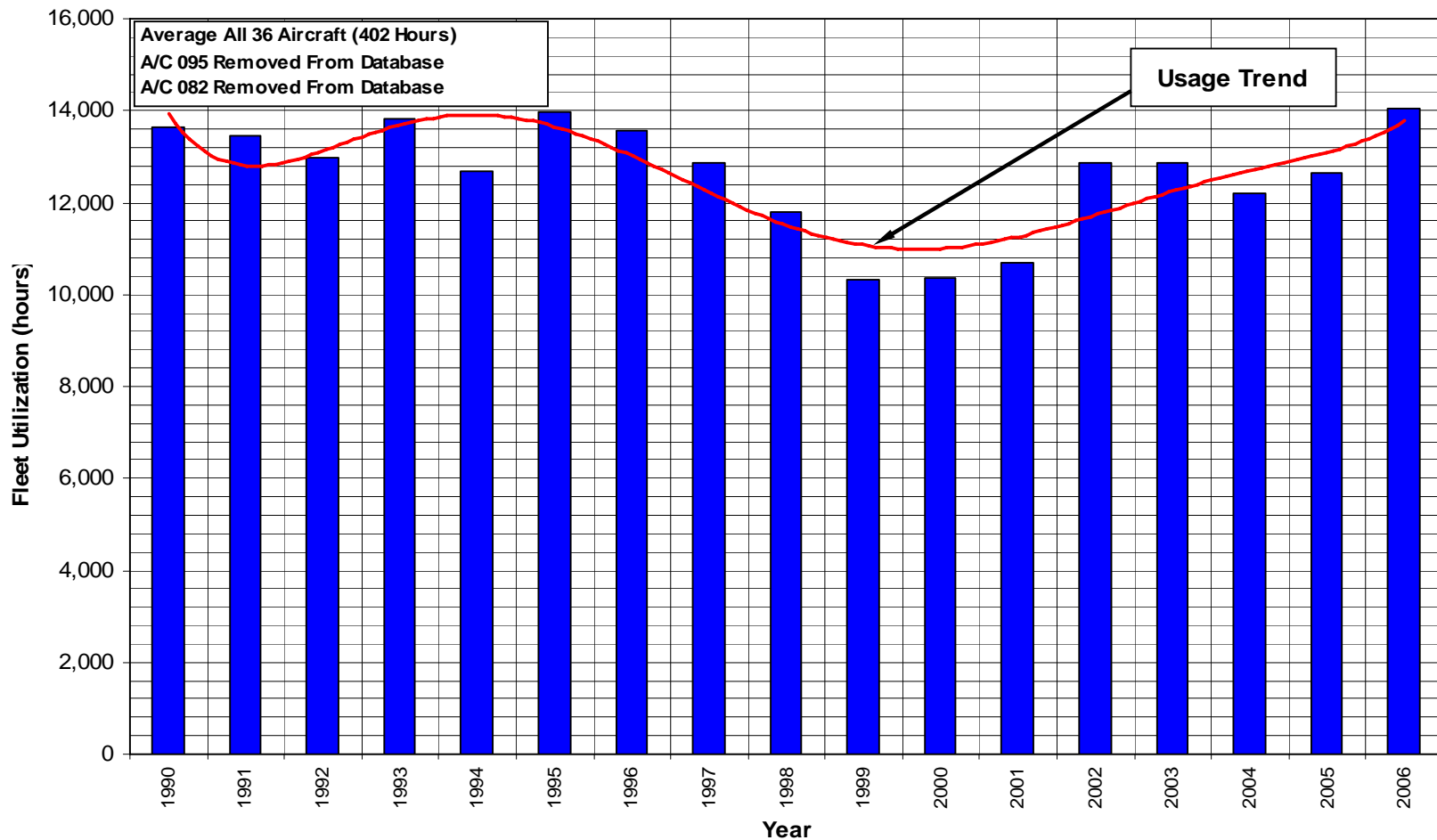
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# U-2S Aircraft Usage Trend



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17 Year (1990-2006) Annual Fleet Utilization (Active A/C Only)  
U-2 Aircraft Excluding NASA, Flight Test, & Trainers





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# U-2 Current Status



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- **OEF/OIF have significantly altered aircraft usage**
  - Longer sorties/heavier take off weights, more operational sorties
  - ASIP plan updated to reflect new mission mixes
- **Small fleet, “Grey Beard” Engineering staff compensate for limited automated data collection and reduction**
- **Reliability Centered Maintenance Analysis (RCMA)**
  - ASIP analysis is starting point for Structurally Significant Items analysis
  - 45 single load path elements will be analyzed



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# U-2 Current Status



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- **No failures of primary structure**
- **Few cracks in primary structure**
  - Most result of poor fit up/preload at initial build
  - Few result of mis-manufactured parts
- **Few corrosion issues**
- **Nuisance cracks**
  - Typically in .032/.040 skins at knife edge fasteners
  - Standard “-3” repairs in place and effective
- **Fleet-wide, airframes have >60,000 flight hours remaining**



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**QUESTIONS?**