Operational Service Life Evaluation for the United States Forest Service P2V-5/-7 Aircraft

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Outline

- *Introduction*
- *Background*
- *Program Objectives*
  - *Phase 1 – Baseline Evaluation*
  - *Phase 2 – Airtanker Evaluation*
  - *Phase 3 – Continued Tracking / Fleet Management*
- *Conclusions*

Introduction

- *New Criteria Established for USFS Airtanker Fleet*
- *USFS Criteria Based on FAA and NTSB Findings*
- *P2V Fleet is First Airtanker Evaluated Under New Criteria*
- *Evaluation Based on FAA Criteria for Damage Tolerance*
- *Evaluation Addresses Baseline and Airtanker Usage*
- *Final Product is to develop the following items:*
  - *FAA DTA Baseline Evaluation of Wing and Tail*
  - *FAA Instructions for Continued Airworthiness*
  - *USFS Operational Service Life*
  - *USFS Airtanker Usage Evaluation*

P2V First Employed by USFS as an Airtanker in 1971

P2V-5/-7 Aircraft Currently Account for over 50% of USFS Large Airtanker Fleet and are vital to operations

Background

- *P2V Designed in 1945 as a USN Maritime Patrol Aircraft*
- *Multiple P2V variants were produced up to the P2V-7*
- *Production ended in 1962 with a total of 1051 aircraft*
- *Current USFS P2V Airtankers are of the P2V-5 and P2V-7 Series*
- *Aircraft are equipped with four engines (2 recips, 2 jets)*
- *Maximum Take-off Weight of 80,000 lbs*
- *Airframe Designed by Lockheed Martin (LM) to USN specifications*
- *Designed to static strength requirements with limited fatigue evaluation*
- *Japanese Maritime Self Defense Force Produced P2V-7 under license*
- *JMSDF Produced 42 P2V-7 under license and 83 P2J by Kawasaki*
- *JMSDF Performed Full Scale Fatigue Testing of a P2V-5 airframe*
- *Last Operational JMSDF P2J was retired in 1995*

USN P2V-5/-7 Served Predominantly as an ASW Patrol Aircraft

BUNO 124870 provided to JMSDF for Full Scale Fatigue Testing

Program Objectives

Phase 1 – Baseline Evaluation

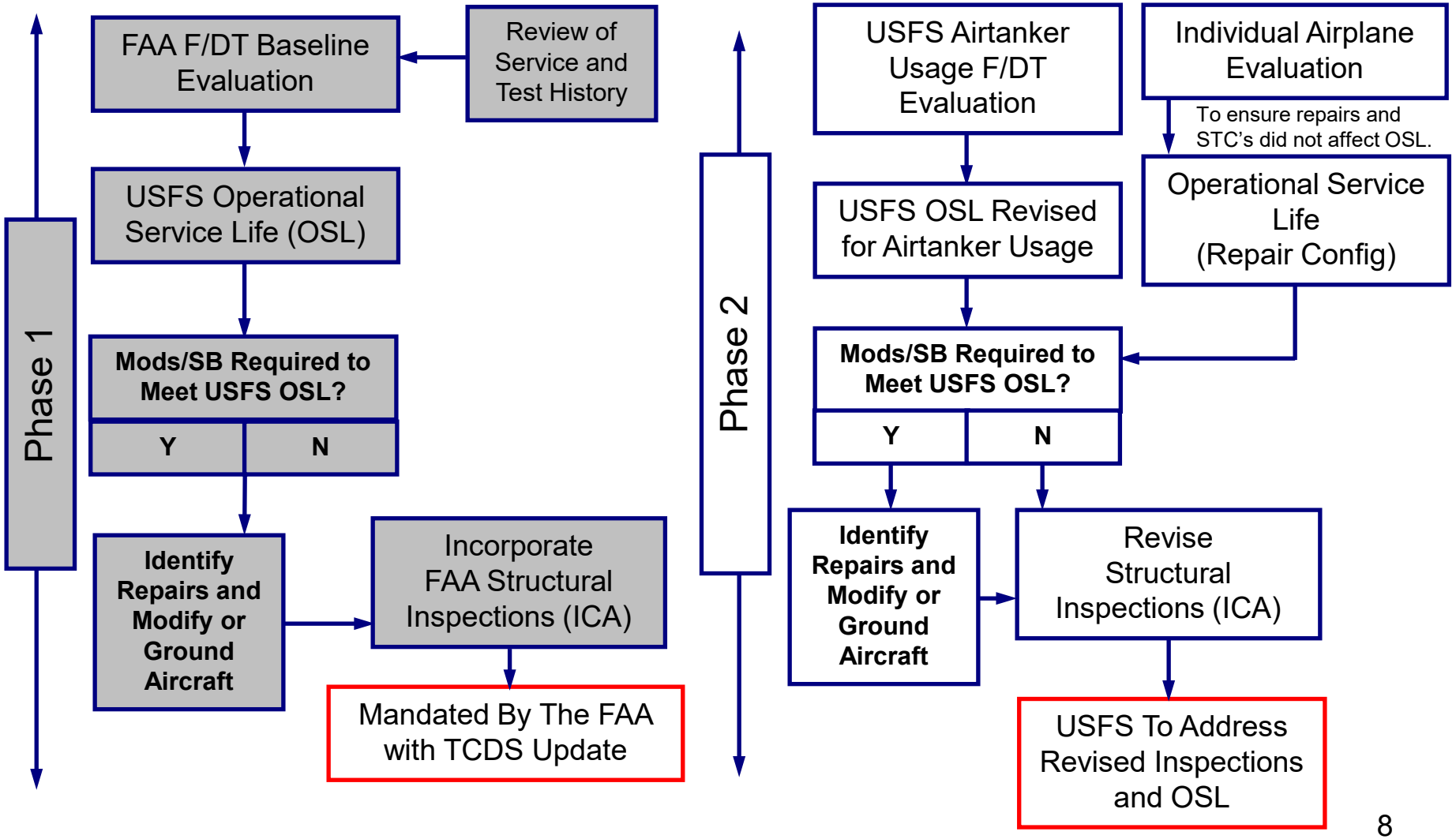
- ***Baseline F/DT Evaluation to FAA Criteria***
- ***FAA Approved ICA based on F/DT***
- ***USFS OSL based on WFD Evaluation***

Phase 2 – Airtanker Evaluation

- ***USFS Airtanker Usage Evaluation***
- ***Revised USFS ICA and OSL Based on Airtanker Usage***

Phase 3 – Continued Fleet Management

- ***Entire Fleet to be Instrumented***
- ***Continued Tracking and Recording of Fleet***


Phase 1
FAA F/DT Baseline Evaluation
Review of Service and Test History
USFS Operational Service Life (OSL)
Mods/SB Required to Meet USFS OSL?
Y
N
Identify Repairs and Modify or Ground Aircraft
Incorporate FAA Structural Inspections (ICA)
Mandated By The FAA with TCDS Update
Phase 2
USFS Airtanker Usage F/DT Evaluation
Individual Airplane Evaluation
To ensure repairs and STC's did not affect OSL.
USFS OSL Revised for Airtanker Usage
Operational Service Life (Repair Config)
Mods/SB Required to Meet USFS OSL?
Y
N
Identify Repairs and Modify or Ground Aircraft
Revise Structural Inspections (ICA)
USFS To Address Revised Inspections and OSL

Phase 1 - Baseline Evaluation

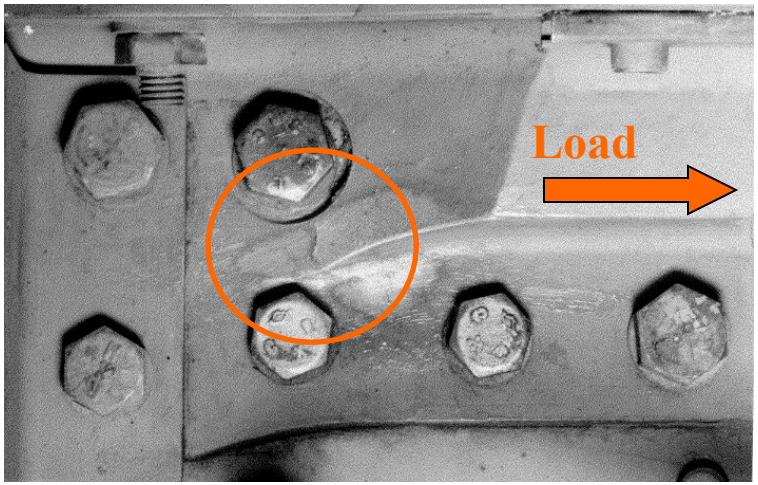
Review of Test and Service History

- *USN and Airtanker Operator Records*
- *JMSDF Full Scale Fatigue Test*

F/DT Evaluation

- *Analysis Performed to Current FAA FAR 25.571*
- *DTA performed at all PSE for both local and acreage areas*
- *Fatigue analysis performed to address local details and WFD*
- *Results utilized in the development of FAA ICA*

Test and Service History

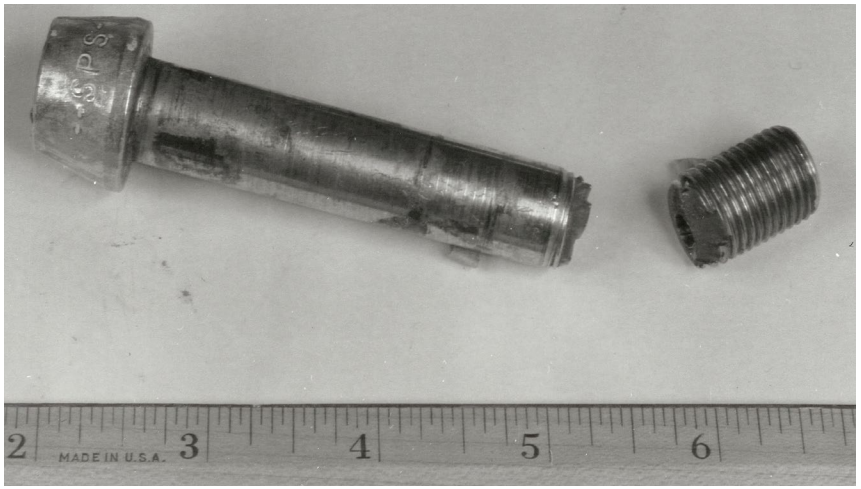


Fatigue Crack in WS192 Spar Attach Fitting

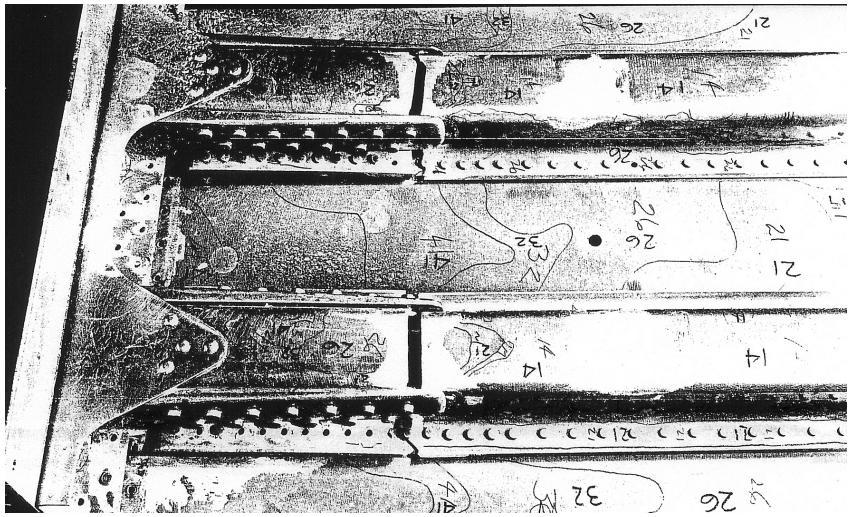
- *Cracks (~0.625") found on two separate aircraft (1970) in service*
- *Fittings replaced and all aircraft inspected*
- *Treated as isolated case (fleet being phased out)*

Cracked Tension Attach Bolts

- *WS192 Attach bolts failed during full scale fatigue test*
- *Primary cause was lack of torque*
- *One instance of Jet Pod bolt failed in service (Jet Pod attaches to wing with only 3 bolts)*



Test and Service History (Contd.)

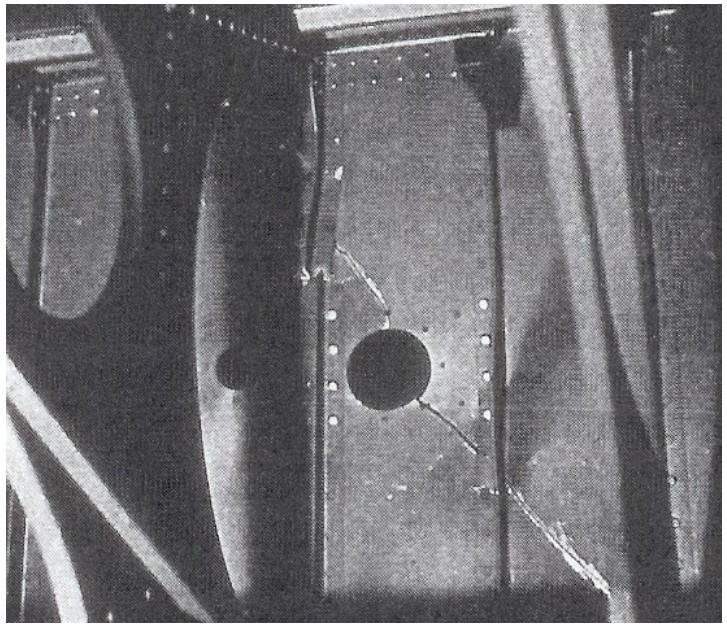


WS215 Rear Spar Web Failure

- *Discovered on Full Scale Fatigue Test*
- *Failure occurred at local cutout and progressed to complete failure of web*
- *Main cause is presence of cutout in a web designed to buckle at 60% limit load*

WFD Stringer Failures at WS192 Joint

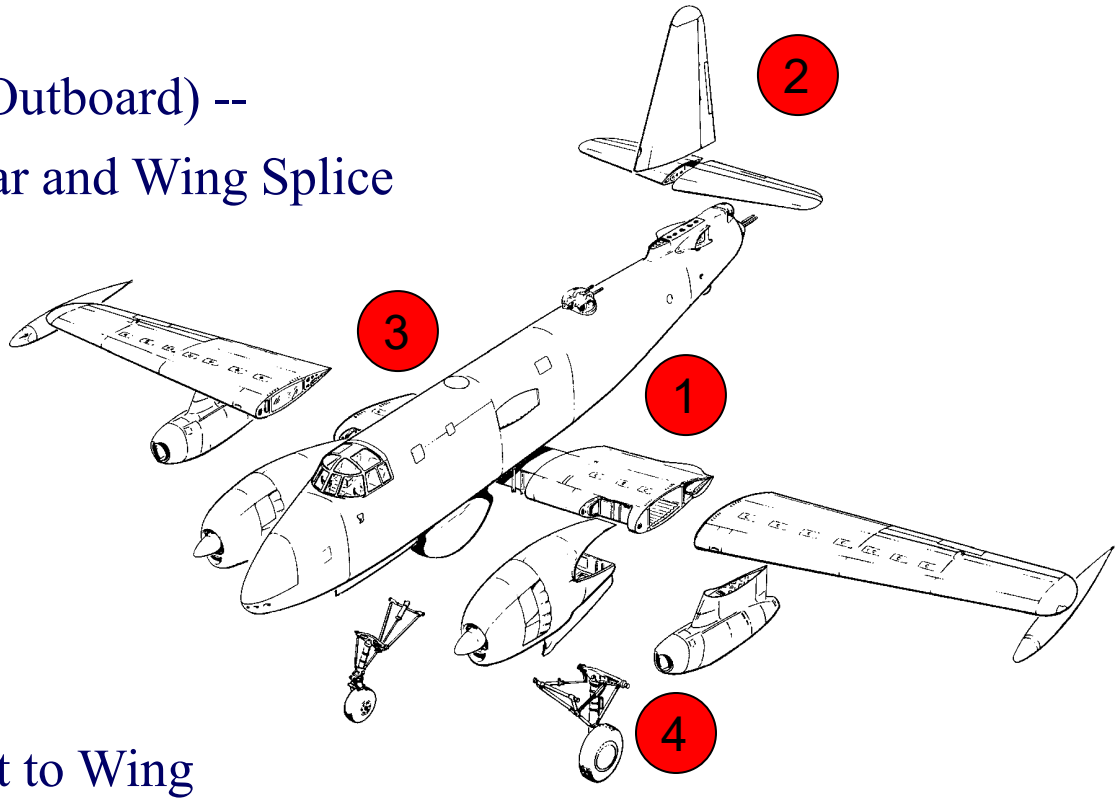
- *Discovered on Component Fatigue Test*
- *Failures caused by multi element damage (MED) to stringers at 1st row in splice joint*



F/DT Baseline Evaluation - Structure Analyzed

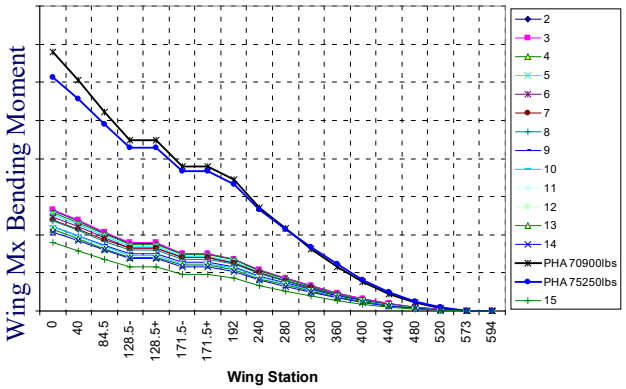
Components Analyzed:

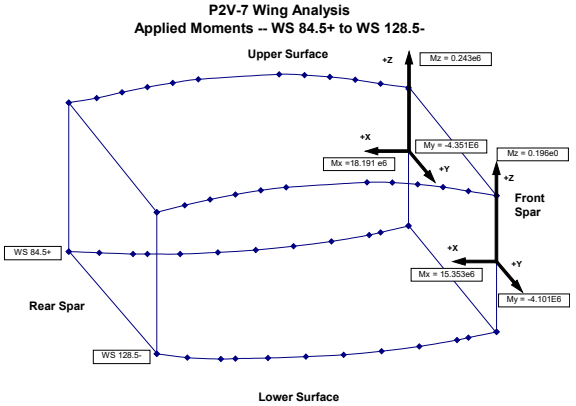
1. Wing (Center and Outboard) --
   Including Rear Spar and Wing Splice



2. Empennage
3. Nacelle Attachment to Wing
4. Landing Gear Attachment to Wing

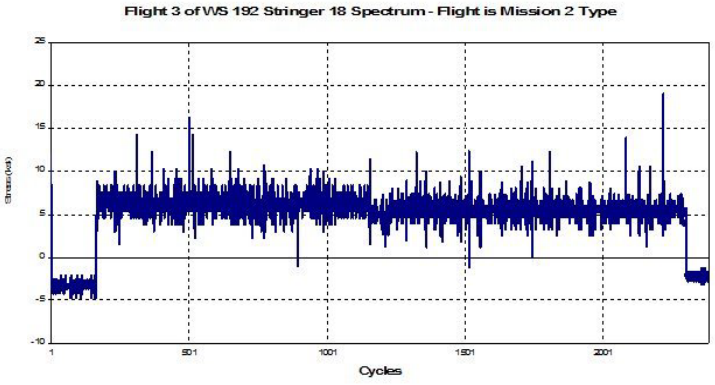
F/DT Baseline Evaluation - Loads and Spectrum Development





External Loads

BoxBeam Internal Loads

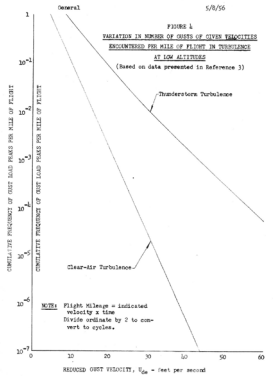


Specgen Flt by Flt Spectrum

TABLE II

Frequency of maneuver loads

Number of times per thousand hours that load factor is experienced				
Percent of maximum (positive) symmetrical limit load factor (column 3 of table I of Specification MIL-A-8861)	Flight maneuver load spectrum			
	A	B	C	D
95	17,000	25,000		
85	9,500	10,000	10,000	
75	6,500	3,500	3,000	1,000
65	4,500	1,000	1,000	150
75	2,500	500	300	20
85	1,500	200	100	3
95	300	75	30	0.5
105	150	25	10	0.05
115	40	10	3	
125	16	3	2	
Percent of minimum (negative) symmetrical limit load factor (column 4 of table I of Specification MIL-A-8861)	A	B	C	D
0	500	5	0.7	
10	200	2	0.5	
20	100	1	0.25	
30	60	0.25		
40	35			
50	30			
60	25			
70	20			
80	15			
90	10			
100	5			
110	3			

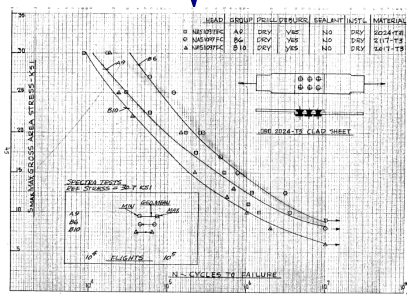


Mil-A-8866 Exceedance Data

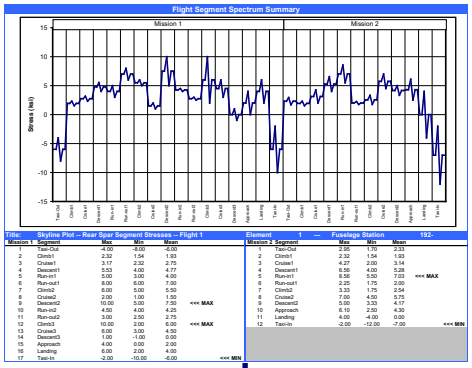
F/DT Baseline Evaluation - Fatigue Analysis Method

Fatigue Analysis
(Sequence Accountable Method)

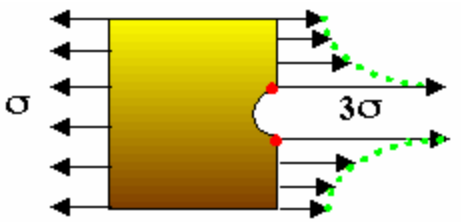
Material Data
(Joint data for various Kt)



Stress Spectrum



Stress Severity Factor (SSF)



● = Point of maximum stress

Fatigue Life/SF

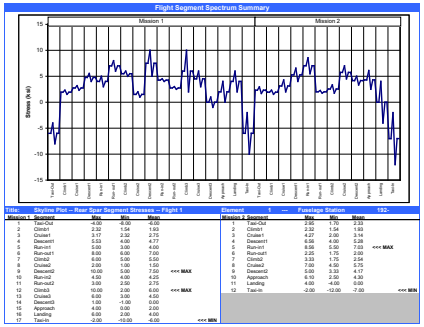
F/DT Baseline Evaluation – Crack Growth Analysis Method

Crack Growth Analysis

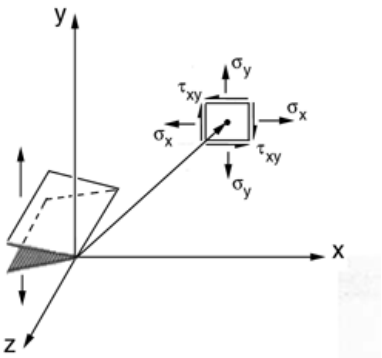
Material Data

- Crack Growth Rates (da/dN)
- Fracture Toughness (Kc and Kic)
- Fty

Stress Spectrum



Stress Intensity Solution (Beta)



Distribution of stresses in vicinity of crack tip

Residual Strength Analysis

Determines at what point crack growth analysis must terminate.

Based upon damaged part's capability to carry limit load.

Crack Growth Life

Phase 1 - (Contd.)

Mandatory Modifications

- *Addresses Local PSE details with poor fatigue lives*

FAA Instructions for Continued Airworthiness (ICA)

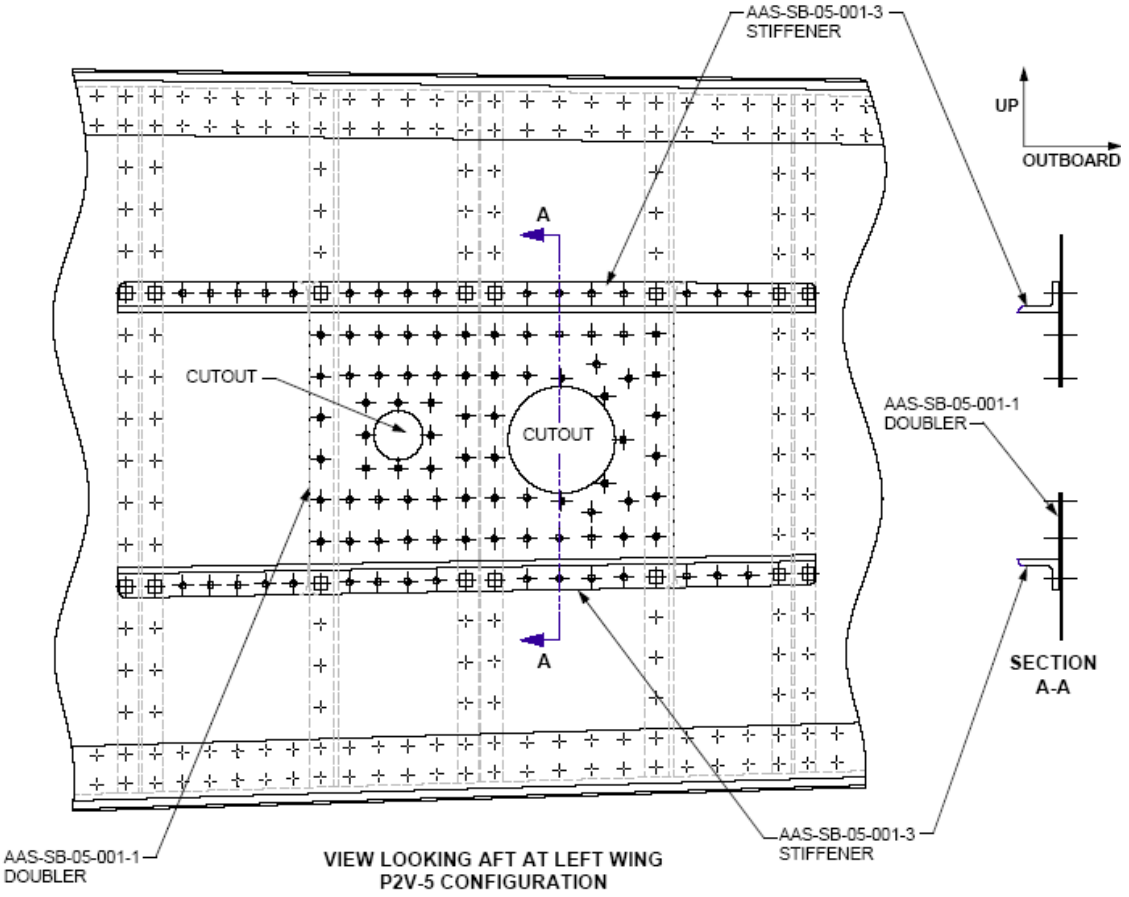
- *Developed in accordance with FAR 25.1529*
- *Provides Airworthiness Limitations for:*
  - *DTA Based PSE Inspections*
  - *Component Life Limitations*
- *Provides Visual and NDT Procedures*

Inspection Findings to Date

Mandatory Modifications / Service Bulletin

SB Mod to WS192 Rear Spar Web

- ***Reinforces cutout***
- ***Stiffens web so that it is now shear resistant***



FAA ICA

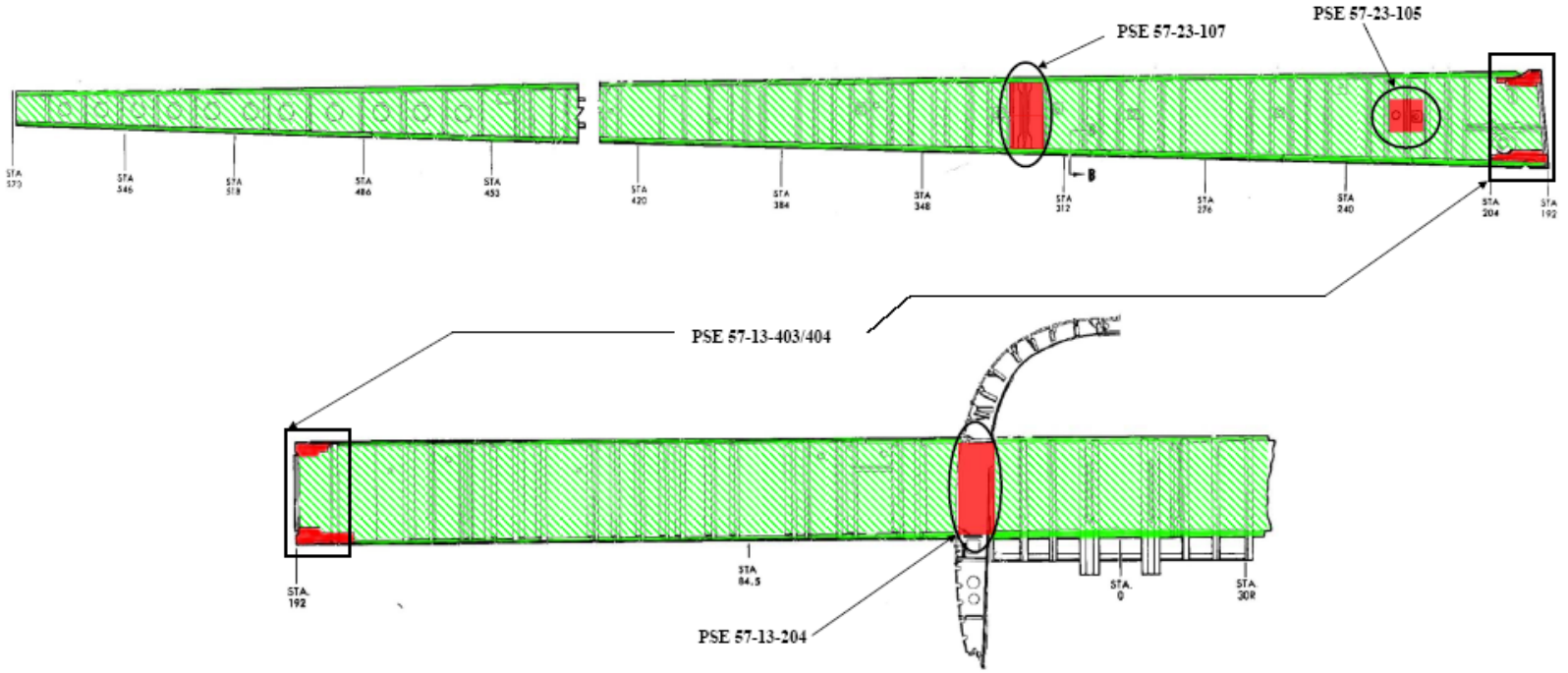
Airworthiness Limitation Section (ALS) for Wing

- *Sets initial and repeat intervals*
- *Specifies both local and acreage inspections*

PSE Number	Principle Structural Element	Threshold Interval (Hours)	Repeat Interval (Hours)	Repeat with SB AAS-SB-05-001	Access	Type
57-16-101	Stringer 17 Outbd WS 40 to Inbd Nacelle at Lwr Access Holes	FAA AD 2002-19-13				
57-16-102	Center and Outer Wing Access Hole Panel Attach Clips	8,650	6,350		INT	VIZ
57-23-103A	Outer Wing Front and Rear Spar Webs	10,000	6,350		EXT	VIZ
57-23-103B	Outer Wing Front and Rear Spar Webs	10,000	6,350		EXT	NDT
57-23-104	Outer Wing Spar Caps WS 192 to WS 573	10,000	425		EXT	NDT
57-23-105	Outboard Wing Rear Spar – Rear Spar WS 215	6,150	250	6,475	EXT	NDT
57-26-106	Outboard Wing – Lwr Skin at Access Hole Cutouts	10,000	2,325		EXT	NDT
57-23-107	Outboard Wing Rear Spar – Web Splice WS 332	8,650	6,350		EXT	NDT
57-16-201A	Center Lower Wing Access Holes and Penetrations	10,000	1,050		INT	NDT
57-16-201B	Center Upper Wing Access Holes and Penetrations	9,800	750	2,275	INT	NDT
57-11-202	Skin to Fuselage Attachment WS 40	10,000	1,025		EXT	NDT
57-14-203	Wing Rib Shear Ties at WS 40, WS 128.5 and WS 171.5	10,000	6,350		INT	VIZ
57-13-204	WS 40 Wing to Fuselage Attachment – Rear Spar	8,650	5,725		INT	NDT
57-11-301	Lower Wing Skin at Front and Rear Spar Cap Attach	10,000	300		EXT	VIZ
57-13-302	Center Wing Front and Rear Spar Caps	8,650	300		INT	VIZ
57-13-303A	Center Wing Front Spar Webs	8,650	6,350		INT	VIZ
57-13-303B	Center Wing Front Spar Webs	8,650	6,350		INT	NDT
57-11-304	Skin Shear Splice at WS 84.5	10,000	400	5,000	EXT	NDT
57-13-305	Center Wing Rear Spar Webs (WS 0 to 40)	8,650	2,350		INT	NDT
57-13-306A	Center Section Wing Rear Spar Web (WS 40 to 192)	8,650	2,350		EXT	VIZ
57-13-306B	Center Section Wing Rear Spar Web (WS 40 to 192)	8,650	4,000		EXT	NDT
57-13-401 thru -404	WS 192 Center and Outer Wing Spar Cap and Splice Fittings	8,650	975	4,000	INT	NDT
57-22-405	WS 192 Center and Outer Wing Stringers and Splice Fittings	10,000	475		EXT	NDT
57-27-406	WS 84.5 & WS 192 Center and Outer Wing Attach Bolts	2,250	1,000		EXT	RR/NDT
57-15-407	WS 84.5 Center Wing Stringers and Splice Fittings	10,000	475		EXT	NDT
57-14-501	Wing Rib Strut Lugs at WS 128.5 & 171.5	8,650	6,350		INT	NDT
57-17-502	Engine Nacelle and WS 128.5 & 171.5 Rib Attach Bolts	5,175	5,175		INT	RR/NDT
57-15-503	Engine Nacelle Attachment – Upper Rib Cap Fitting	8,650	6,350		INT	NDT
57-27-601	Jet Pod Attachment – Front and Rear Spar Attach Bolts	1,850	1,850		EXT	RR
57-25-602	Jet Pod Attachment – Front and Rear Spar Attach Fittings	8,650	3,325		EXT	NDT
57-35-701	Outboard Tip Tank – Splice Fitting Horizontal Flange	8,650	6,350		INT	NDT
57-35-702	Outboard Tip Tank – Splice Fitting Vertical Flange	8,650	6,100		INT	NDT

Table C.1 – P2V-5 Wing Box PSE Inspection Requirements

FAA ICA (Contd.)



GENERAL ACREAGE PSE INSPECTION AREAS

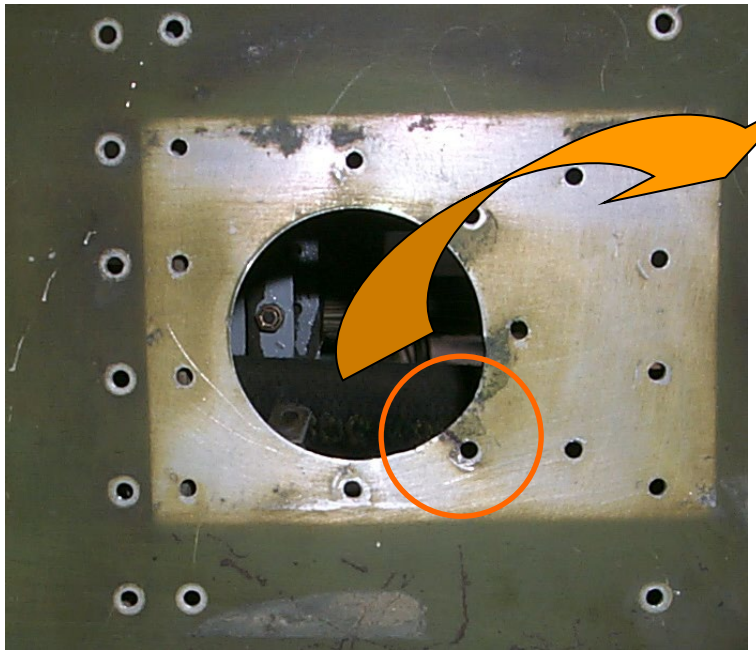
- PSE 57-13-302 Center Wing Rear Spar Upper and Lower Caps WS0 to WS192
- PSE 57-13-305 Center Wing Rear Spar Web WS0 to WS40
- PSE 57-13-306 Center Wing Rear Spar Web WS40 to WS192
- PSE 57-23-103 Outer Wing Rear Spar Webs
- PSE 57-23-104 Outer Wing Rear Spar Upper and Lower Caps

SPECIFIC DETAIL PSE INSPECTION AREAS

- PSE 57-13-204 Rear Spar to Fuselage Attachment WS40
- PSE 57-13-403/404 Rear Spar Cap Splice at WS192
- PSE 57-23-105 Rear Spar Web Cutout at WS215
- PSE 57-23-107 Rear Spar Web Splice at WS332

Summary of General and Detail Wing Rear Spar ICA Inspections

ICA Inspection Findings

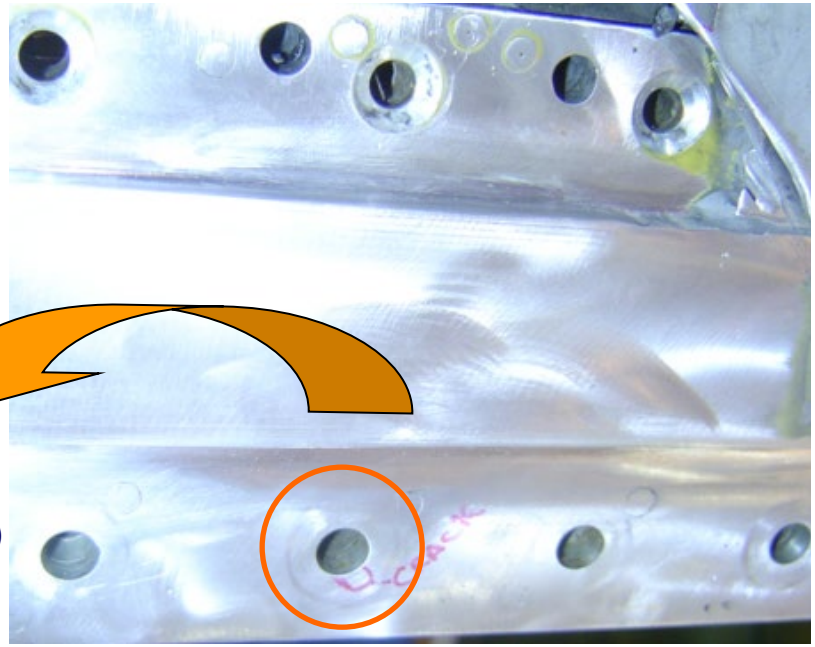


WS192 Spar Cap at Attach Fitting

- *Fatigue crack found at bolt hole at attachment to fitting (0.015" corner crack)*
- *Aircraft had approx. 10000 hours*

WS215 Rear Spar Web

- *Edge ligament fatigue crack found at access hole originating from satellite hole*
- *Aircraft had approx. 11600 hours*



Phase 1 - (Contd.)

USFS Operational Service Life (OSL)

- *Established as a goal for the fleet*
- *Based on WFD evaluation results*
- *WS192 Wing Joint is most WFD susceptible area*
- *WFD Life for WS192 Joint is 15,000 Flight Hours*
- *Baseline USFS OSL set at 15,000 Flight Hours*

Phase 2 – Airtanker Usage Evaluation

Instrumentation and Recorded Parameters

- ***Generic and Discrete Flight Parameters***
- ***Strain Gage Locations***
- ***Pilot Supplemental Data***

Evaluation of Recorded Data

Analysis Update

Revisions to ICA and OSL

Instrumented P2V Aircraft

P2V-7 Tanker 48

Minden Aviation

Ex-BUNO 148357

P2V-5 Tanker 44

Neptune Aviation

Ex-BUNO 128422

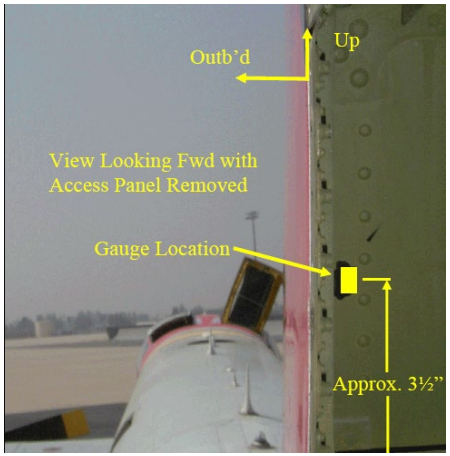
Recorded Parameters

Parameter	Units	Low	High	Trigger
Aircraft Acceleration – Nzcg	g	-1.0	+4.5	Yes
Roll Acceleration	rad/sec^2	-30	+30	Yes
Airspeed	knots	0	450	No
Altitude	feet	-500	20,000	No
Fuel Level	gallons	0	2,000	No
Aileron Position	degrees	Max Down	Max Up	No
Varicam Position	degrees	Max Down	Max Up	No
Elevator Position	degrees	Max Down	Max Up	No
Flap Position	degrees	Max Down	Max Up	No

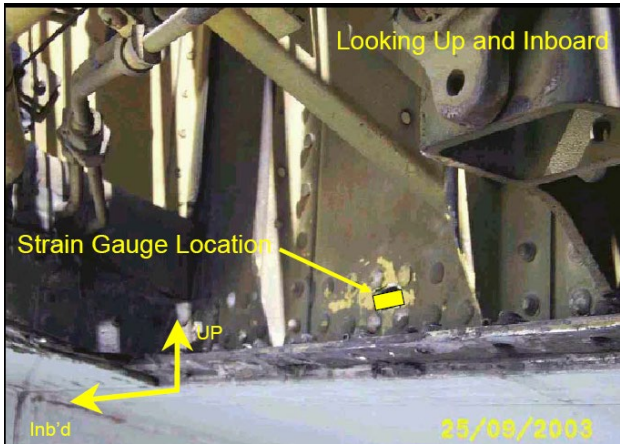
Parameter
Electrical Power On/Off
Landing Gear Up/Down
Retardant Tank Drop Door #1
Retardant Tank Drop Door #2
Retardant Tank Drop Door #3
Retardant Tank Drop Door #4
Retardant Tank Drop Door #5
Retardant Tank Drop Door #6
Ignition of Jet Engines
% Jet RPM, Channel A
% Jet RPM, Channel B

Strain Gage Locations

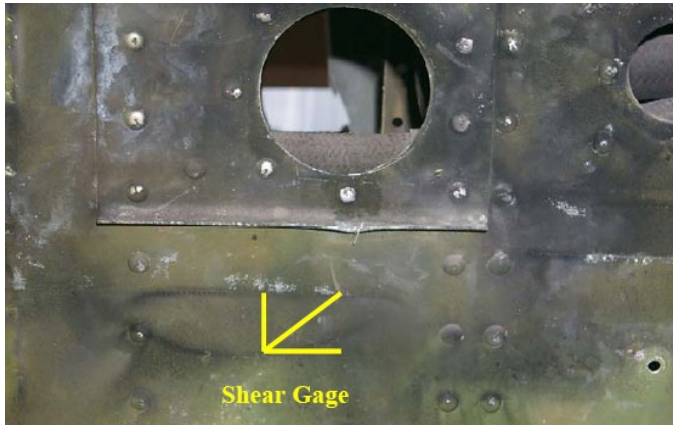
Parameters		
Strain Gage #1 – wing	WS61 Left Lwr Spar Cap	Axial gage
Strain Gage #2 – wing	WS61 Right Lwr Spar Cap	Axial gage
Strain Gage #3 – horizontal	HSS34 Left Lwr Spar Cap	Axial gage
Strain Gage #4 – vertical	VSS34 Front Left Spar Cap	Axial gage
Strain Gage #5 - wing	WS61 Left Upper Spar Cap	Axial gage
Strain Gage #6 - wing	WS46 Right Upper Spar Cap	Axial gage
Strain Gage #7 - wing	WS46 Right Lwr Cover Strg 18	Axial gage
Strain Gage #8 - wing	WS180 Front Lwr Spar Cap	Axial gage
Strain Gage #9 - wing	WS197 Rear Lwr Spar Cap	Axial gage
Strain Gage #10 – wing	WS215 Rear Spar Web	Rosette Z gage
Strain Gage #11 – wing	WS215 Rear Spar Web	Rosette Y gage
Strain Gage #12 - wing	WS215 Rear Spar Web	Rosette X gage



Gage #4



Gages #1 & 2

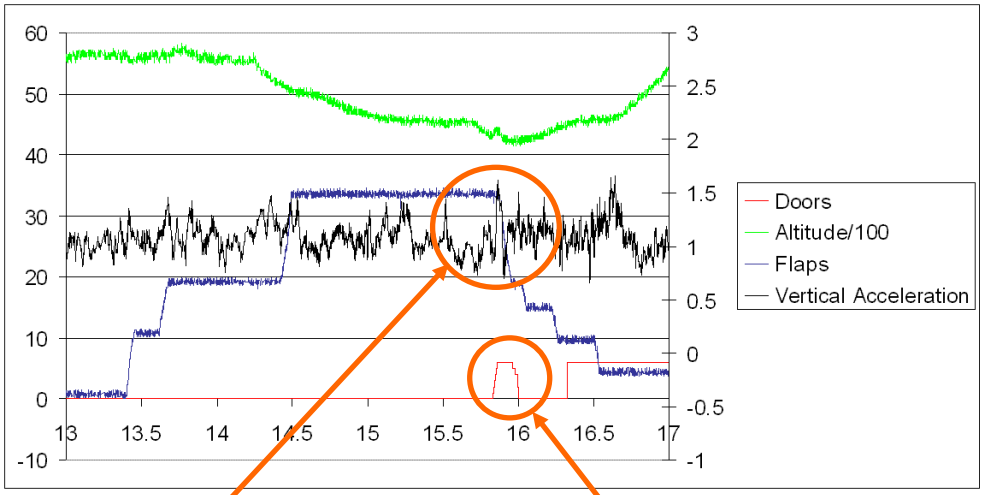


Gages #10, 11, 12

Pilot Supplemental Data

Flight Date: 8/16/05	Tanker Number:44			
Flight Number	1	2	3	4
T/O Time	1418	1541	1716	1839
Drop Time	1455	6000	1755	1918
In Time	1530	1652	1828	1953
Dept. Base	MSO	MSO	MSO	MSO
Fuel gal.	1800	1400	1600	1200
Ret. Load/Type	FT GTS-R	FT GTS-R	FT GTS-R	FT GTS-R
Dist. To Fire	95	95	95	95
AA or Lead #	LD B08	LD B09	LD B19	LD 49
Drop Alt.	5700	6000	6000	6900
Drop Runs 0/0 = Low Pass 3/6 = 3 Doors/Coverage 6	6/6s COV 6	6/6s COV 6	6/6s COV 6	6/6s COV 8
Flaps 20, Full	FULL	FULL	FULL	FULL
PIREP VV/RA, FU, HZ, SQ, TS	SMOKE	SMOKE	SMOKE	SMOKE
TB L, M, S, E	SMOOTH	SMOOTH	SMOOTH	SMOOTH
Approach	LT-DEC-ST-W/S	LT-DEC-ST-W/S	LT-DEC-ST-W/S	RT-DEC-ST-W/S
Exit	Climb-LT, Climb ST	Climb RT-LT-ST	Climb LT-ST	Climb LT-ST
Remarks	A/C WT 48150+ FUEL + RET LOAD T/O CG 3% MAC			

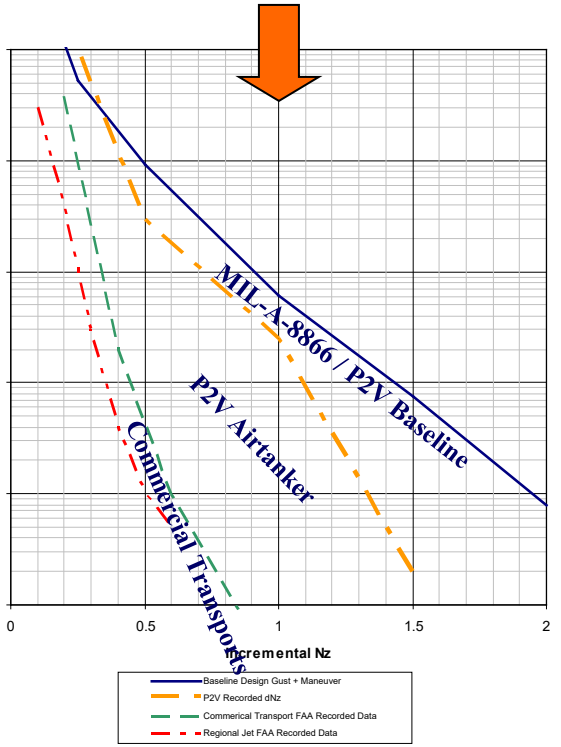
Evaluation of 2005 Recorded Data



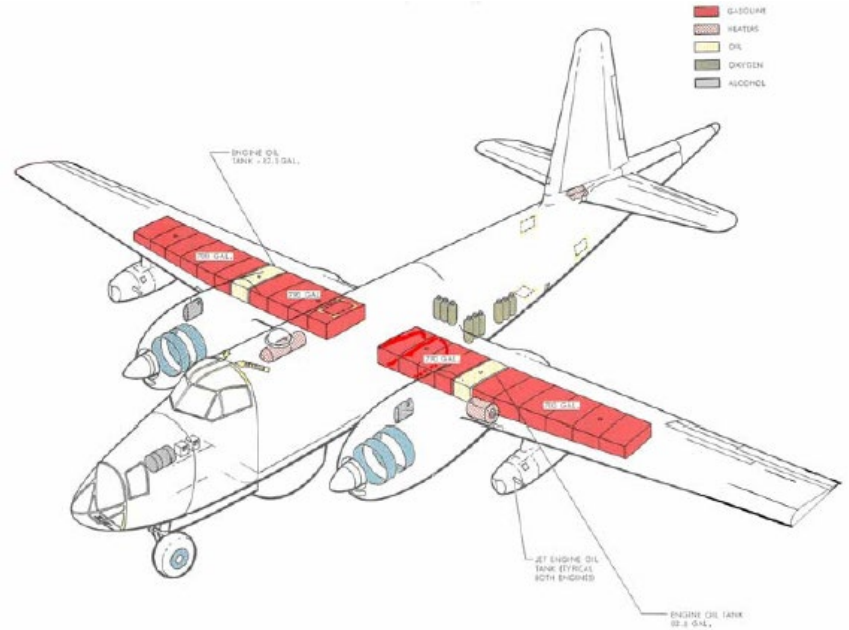
Nz spike noted during drop

Opening of doors during drop

Recorded Nz falls between Baseline Curve & Commercial Transport Data

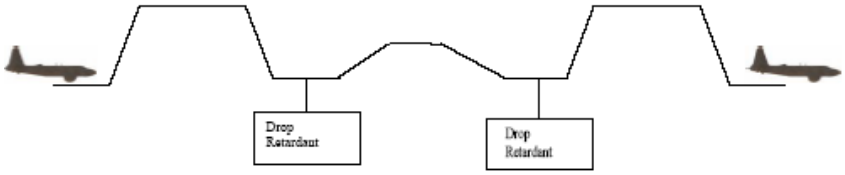


Analysis Update and Revision to ICA and OSL



P2V Airtanker Configuration

- ASW Equipment Removed
- No Tip Pods
- Fuel Bladders replace armored tanks
- Retardant Tank Weight



Mission Profiles

- Based on 2005 Season Data
- Incorporates Airtanker Wt Distr.
- Accounts for different types of drops

	Fuel (lbs)	GW (lbs)	Retardant (lbs)	Airspeed (knots)	Altitude (feet)	Distance (nmi)	Duration (min)
Baseline	11700.0	77550	19200				
taxi-in/take-off	-704.2	76845.8		10	5400	0.55	3.30
climb1	-142.2	76703.6		187	5400	5.96	1.90
cruise1	-499.7	76203.9		170	6600	41.93	14.80
descent1	-121.6	76082.4		170	6600	10.20	3.60
drop 1	-1.3	66481.1	-9600	160	4000	0.13	0.0500
climb 2	-167.0	66314.1		140	4000	4.37	1.85
descent2	-24.4	66289.6		170	5400	3.12	1.10
drop 2	-1.1	66688.6	-9600	150	5000	0.13	0.050
climb3	-161.2	66527.3		196	5000	7.82	2.35
cruise2	-82.3	66445.0		200	7600	13.33	4.00
descent 3	-61.8	66383.2		160	7600	8.00	3.00
approach/land	-44.9	66338.4		52	5400	1.91	2.20
taxi-out	-106.1	66232.3		10	5400	0.87	5.20
Fuel Remaining	9582.3				tot	98.32	43.40

Phase 3 – Continued Tracking/Fleet Management

Instrumentation of Remaining P2V Fleet

Monitor and Accumulate Recorded Data

Update Airtanker Usage Evaluation

Establish USFS Airtanker Specification Document

- ***Set Baseline Requirements***
- ***Establish Evaluation Criteria***
- ***Establish Service Goal Requirements***

Conclusions

- ***P2V Baseline Evaluation Completed***
- ***FAA ICA for P2V Baseline Completed***
- ***Baseline ICA Currently Being Incorporated by Operators***
- ***P2V Airtanker Fleet has not exceeded Baseline OSL***
- ***Airtanker Usage Currently Being Evaluated***
- ***Entire P2V Airtanker Fleet to be Instrumented***
- ***Continued Evaluation of Airtanker Usage beyond 2006***
- ***USFS to Utilize P2V Program to establish Generic Airtanker Specifications***