OPERATIONAL SERVICE LIFE EVALUATION FOR THE UNITED STATES FOREST SERVICE P2V-5/-7

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ABSTRACT

The P2V is a four engine ex-military aircraft originally designed by the Vega Corporation (a division of the Lockheed Corporation) in 1945 for the US Navy. Its primary design role was that of a maritime patrol, reconnaissance and anti-submarine warfare airplane. Various models were manufactured from 1945 starting with the P2V-1 and ending with the P2V-7. A total of 1188 aircraft were manufactured and it was finally phased out of the US Navy in 1978 when it was replaced by the P3V-1 (later renamed P-3A). The last US manufactured aircraft were built in 1962 at the Lockheed Burbank facility alongside the newly designed P3V-1. The type continued to operate with several foreign militaries until 1995 when it was finally retired from military duty. The last military operator of the P2V was the Japanese Maritime Self Defense Force (JMSDF) who were licensed to build P2V-7s and also produced their own turbine powered variant, the P2J.

At the time P2V's were being retired by the US Navy, requirements for modern airtankers were being explored by the United States Forest Service. The P2V was evaluated as a platform for the airtanker role and an FAA Restricted Category Type Certificate A17EA was issued to the USDAFS in 1978. Eventually, over 15 P2V's (both P2V-5 and P2V-7 models) were converted to the airtanker role and have served with great effectiveness in the airtanker role for over 25 years.

As a result of the aging USFS airtanker fleet and the recent accidents involving wing failures due to fatigue damage, the USFS has embarked on developing new strategies for managing their fleet. They have implemented service life evaluation programs consistent with the latest FAA requirements for their existing airtanker fleet. This is being accomplished in an effort to develop baseline FAA certified inspection programs for the airframe. In addition, the USFS is developing fleet tracking and management philosophies in order to assess and monitor the impact the mission usage and severity of the airtanker role has on the structural integrity of the airframe.

This technical paper presents the current progress and objectives of Avenger Aircraft and Services evaluation of the P2V-5 and P2V-7airframes for the United States Forest Service. Since the original design of the P2V airframe predated both military and commercial requirements for fatigue and damage tolerance evaluations, the scope of the program was quite extensive. This paper presents the technical approach, methodologies and results of the baseline evaluation of the P2V airframe to the current FAA fatigue and damage tolerance analysis (DTA) requirements of FAR 25.571. An overview of the resulting FAA inspections for continued airworthiness are provided as well as a discussion of the current efforts of the program which are focused at evaluating the nature of the airtanker mission and the evaluation of its impact to the structural integrity of the airframe.

This paper also presents the USFS approach for implementing the service life evaluation and the tracking efforts into a fleet management approach for the P2V as well as utilizing it as a basis for all future evaluations and acceptance criteria for new platforms.

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INTRODUCTION

The current efforts related to the P2V are as a result of changes in USFS fleet management philosophies stemming from reviews and recommendations by both the NTSB and FAA following the accidents involving the wing fatigue failures incurred in recent years in the airtanker environment. The aircraft contracted by the USFS for the airtanker role are on the average 40 years old and were designed prior to any of the current FAA requirements for fatigue and damage tolerance, including fatigue and damage tolerance based inspections. A large percentage of these aircraft are of ex-military origin and were therefore not originally certificated to FAA requirements. With respect to the P2V, this aircraft was primarily designed to basic static strength requirements and was certificated to US Navy requirements and specifications in 1945. The FAA awarded the USFS a Restricted Category Type Certificate based on the original USN certification requirements and the USN maintenance documents. The existing P2V USN maintenance documents did not include any life limitations, service life limits nor fatigue based directed inspection requirements. As such, the recent recommendations in 2004 from the FAA to the USFS regarding the service life evaluation of the P2V for continued use in the airtanker role included the following statements:

> *"Insufficient engineering data is available to affected operators to define the fatigue state of this aircraft (P2V)." "We (the FAA) propose the following: ....*
>
> *1. Establish a fatigue baseline state for each airplane by using engineering assessments in conjunction with detailed inspections…*
> *2. Using the results from the fatigue baseline…, complete an engineering analysis to predict future inspection intervals*
> *3. Use the results of item 2 above and existing NAVAIR maintenance document information to establish inspection and modification procedures that would be rolled into a revised aircraft inspection program"*

Based on this and other input from the FAA and the recommendations from the NTSB, the USFS established a minimum set of criteria in order to allow aircraft, and specifically the P2V, to operate in the airtanker role. Primarily, the airtankers must have current and valid FAA type certificates. Secondly, the airtankers must have FAA Instructions for Continued Airworthiness (ICA) with a corresponding Airworthiness Limitations Section (ALS) containing DTA based inspections in accordance with current FAR 25.1529 and FAR 25.571 requirements for the baseline operations stated on the FAA type certificate. Thirdly, a USFS Operational Service Life is to be established based on the results of the fatigue evaluation. And lastly, the baseline FAA ICA and USFS OSL must be re-evaluated for the impact of the airtanker environment.

With this in mind, the service life evaluation of the P2V airframe was a significant undertaking as it entailed developing both a complete baseline analysis of the airframe as well as evaluating the airtanker mission. This was done in order to determine the amount of expended airframe fatigue life while under USN usage as well as the damage being accumulated while under the airtanker role. The baseline evaluation was a significant effort since it included developing the original mission utilization and load histories as well as corresponding external and internal loads, detailed stress analyses and fatigue and damage tolerance analysis to the latest FAA requirements of FAR 25.571. This was further complicated by the development and validation of a comprehensive ICA and ALS to the FAA requirements of FAR 25.1529 as well as a very aggressive schedule which required completion within approximately 7 months which was achieved successfully. The airtanker evaluation also includes additional challenges of its own such as the re-evaluation of all critical details utilizing the recorded data which includes the development of external loads for the unique airtanker drop segments of the mission.

Despite the technical challenges related to this effort, the service life evaluation of the P2V has provided several valuable products to both the USFS as well as the operators. First and foremost, the P2V operators are now equipped with an approved inspection document which meets all of the latest FAA fatigue and damage tolerance requirements and provides for the safe continued airworthiness of the airframe to the baseline operations. Secondly, the current evaluation of the airtanker environment will permit updating the inspection requirements to reflect the airtanker operations. In addition, the USFS also has a valuable baseline for the development of additional efforts on their remaining fleet as well as criteria for any future platforms considered in the airtanker role.

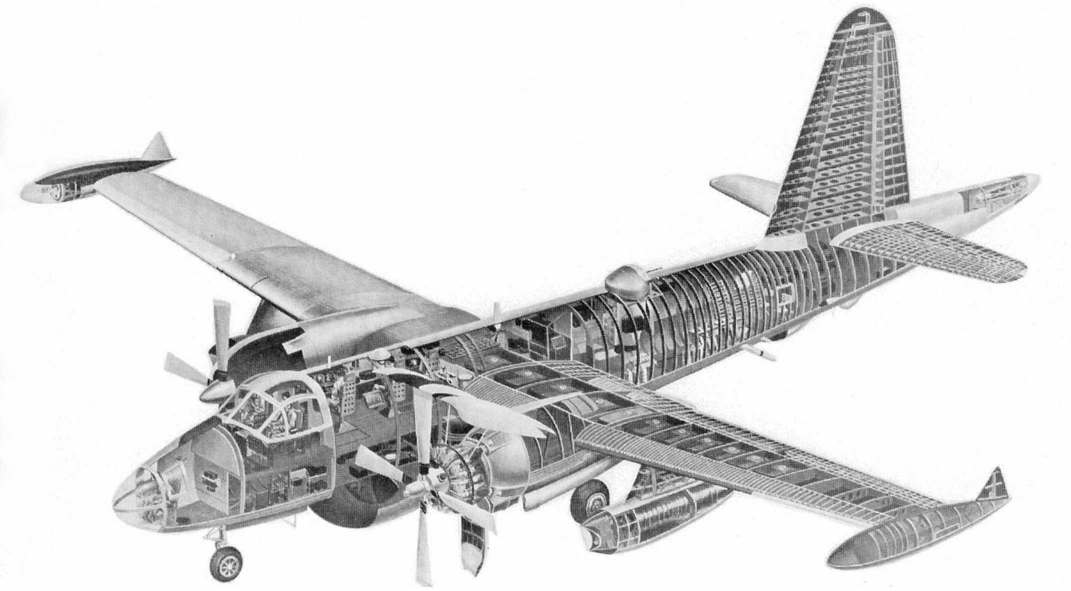
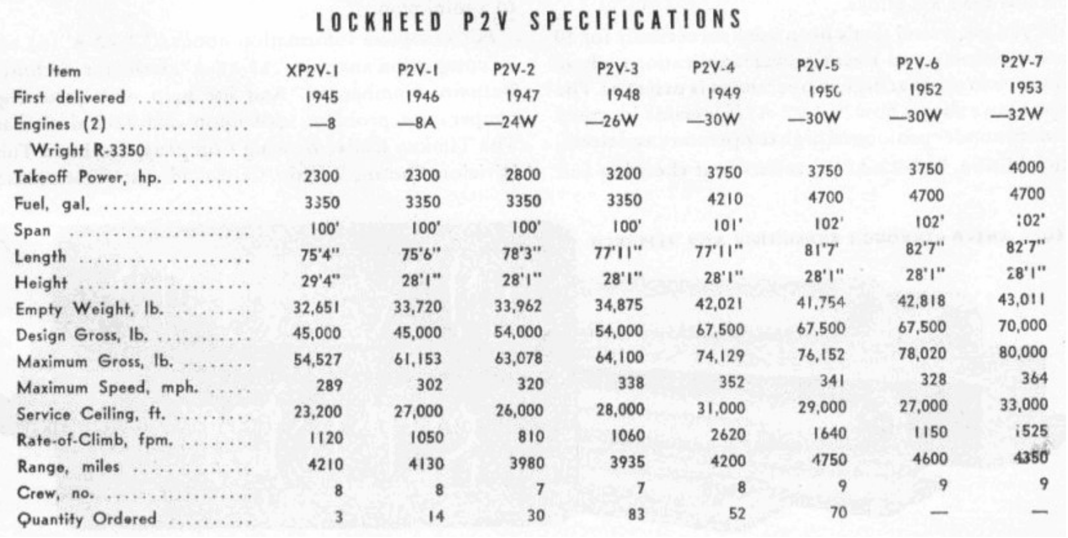


Figure 1 Arrangement of P2V-5/-7 Airframe

BACKGROUND

The P2V developed by Lockheed for the US Navy consisted of a complete series of aircraft all deriving from the original prototype XP2V-1 model aircraft which first flew in 1945. The current aircraft being utilized in the airtanker role are of the final variants of the P2V design being the P2V-5 and P2V-7. Table 1 below illustrates the various P2V models and specifications.



LOCKHEED P2V SPECIFICATIONS

Item	XP2V-1	P2V-1	P2V-2	P2V-3	P2V-4	P2V-5	P2V-6	P2V-7
First delivered	1945	1946	1947	1948	1949	1950	1952	1953
Engines (2)	—8	—8A	—24W	—26W	—30W	—30W	—30W	—32W
Wright R-3350								
Takeoff Power, hp.	2300	2300	2800	3200	3750	3750	3750	4000
Fuel, gal.	3350	3350	3350	3350	4210	4700	4700	4700
Span	100'	100'	100'	100'	101'	102'	102'	102'
Length	75'4"	75'6"	78'3"	77'11"	77'11"	81'7'	82'7"	82'7"
Height	29'4"	28'1"	28'1"	28'1"	28'1"	28'1"	28'1"	28'1"
Empty Weight, lb.	32,651	33,720	33,962	34,875	42,021	41,754	42,818	43,011
Design Gross, lb.	45,000	45,000	54,000	54,000	67,500	67,500	67,500	70,000
Maximum Gross, lb.	54,527	61,153	63,078	64,100	74,129	76,152	78,020	80,000
Maximum Speed, mph.	289	302	320	338	352	341	328	364
Service Ceiling, ft.	23,200	27,000	26,000	28,000	31,000	29,000	27,000	33,000
Rate-of-Climb, fpm.	1120	1050	810	1060	2620	1640	1150	1525
Range, miles	4210	4130	3980	3935	4200	4750	4600	4350
Crew, no.	8	8	7	7	8	9	9	9
Quantity Ordered	3	14	30	83	52	70	—	—

Table 1 P2V Variants and Specifications

The structural configuration and arrangements of the P2V-5 and P2V-7 are very similar in design to the original prototype XP2V-1 but were enhanced over the earlier models due to increases in gross weight. Beginning with the P2V-4, a major strengthening of the wing was incorporated while starting with the P2V-5 outboard jet engines were incorporated for assisted takeoffs at higher gross weights. A significant amount of structural static testing was performed on the various models to include full scale static testing of the XP2V-1, P2V-4, P2V-5, and P2V-7. However, full scale fatigue testing was not performed by Lockheed as it was not required by the US Navy at that time. Some component level fatigue testing of critical wing details was performed on a limited basis. A large number of these reports along with other supporting reports and data were purchased and obtained from Lockheed Martin for use as reference material in the evaluation.

In addition to P2V's built for the USN, several foreign militaries employed the P2V aircraft as well. In particular, the Japanese Maritime Self Defense Force (JMSDF) used a total of 64 P2V-7 aircraft. Lockheed later granted a production license to Japan which built P2V-7 aircraft and subsequently designed and built a Japanese turboprop configured variant named the P2J of which 83 were produced. As part of incorporating the P2V as an integral part of their maritime patrol fleet, the JMSDF performed a full scale fatigue test of a P2V-5 airframe modified to a -7 configuration with the assistance of the USN. The USN supplied the necessary test loads, criteria and an actual airframe on which to perform the test. The aircraft, ex-BUNO 124870, was shipped to Japan and tested in 1968 at the TRDI Tachikawa test facilities. The Japanese Embassy in Washington DC graciously located the relevant test reports and donated them for use in this evaluation.

PROGRAM OBJECTIVES

The basic objectives of this program were to assist the USFS in meeting the NTSB and FAA criteria contained in their recommendations. Essentially, this meant developing an FAA inspection program based on fatigue and damage tolerance analysis and subsequently updating these requirements to account for the airtanker role. The USFS is currently focusing this effort on the wing and empennage as the aircraft operate unpressurized. Thus, the program is distinctly separated into two phases. The first phase encompasses the FAA baseline evaluation of the wing and empennage while the second phase contains the evaluation of the USFS airtanker usage impact. Figure 2 and the following lists illustrate the objectives associated with each of the two phases of the program.

PHASE 1 OBJECTIVES:

- Development of Baseline Mission Profiles per NAVAIR Flight Manual
- Development of Load Histories per Mil-8866
- Development of Aircraft External Loads
- Development of Wing and Tail Internal Loads
- Review of Service and Test Histories
- Selection of Principle Structural Elements for Analysis
- Fatigue(local and for WFD) and DTA of wing and empennage PSE details
- Residual Strength Analysis
- Development and Validation of PSE Inspection Procedures
- Identification of Component Life Limitations
- Development of FAA ICA and ALS
- Development of USFS OSL based on WFD evaluation

PHASE 2 OBJECTIVES:

- Evaluation of Recorded Data
- Development of Airtanker Mission Profiles
- Re-evaluation of Load Histories based on Recorded Data
- Development of External Loads
- Development of Internal Loads
- Re-evaluation of PSE details to Airtanker Mission
- Determination of Impact to ICA and OSL

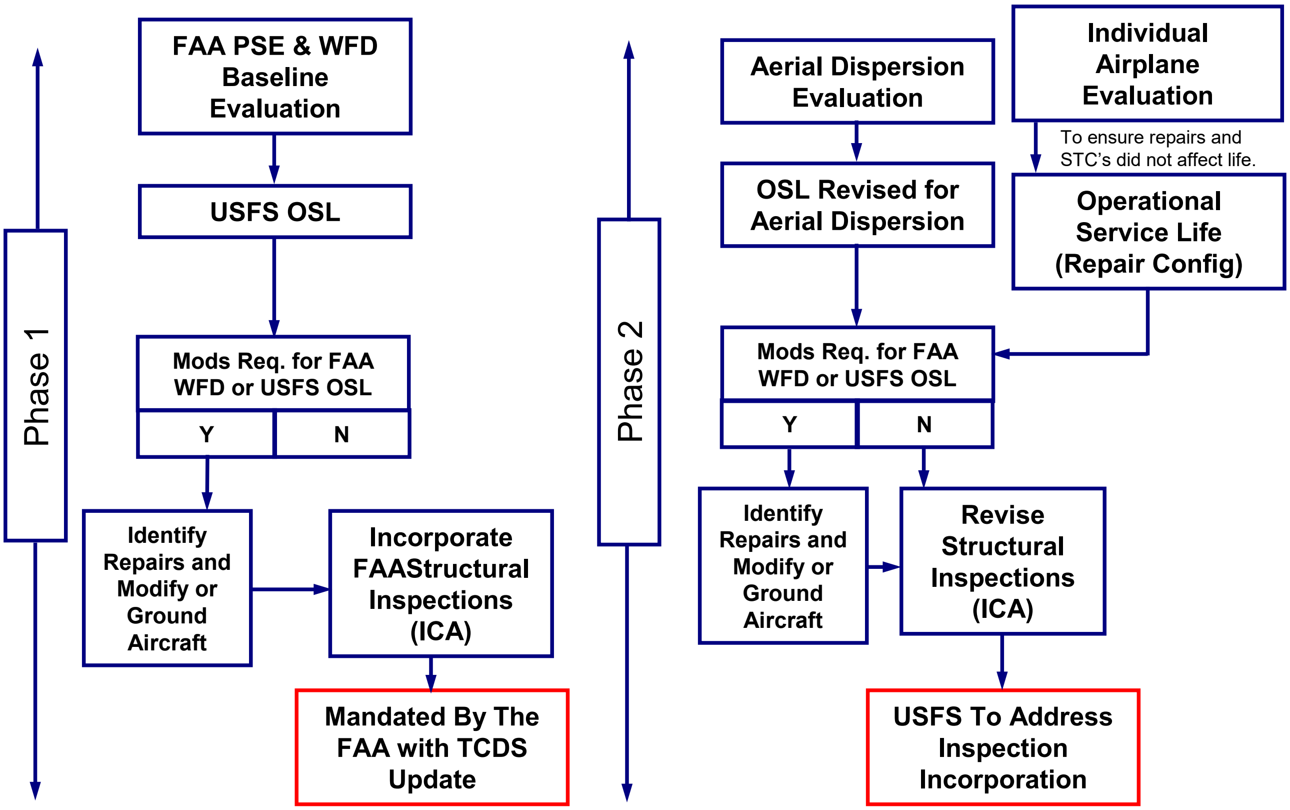


Figure 2 Objects and Corresponding Phases of P2V Evaluation

PHASE 1 – BASELINE EVALUATION

The baseline fatigue and damage tolerance evaluation of the P2V-5/-7 wing and empennage was performed through the use of some existing data but predominantly involved a complete development of baseline mission profiles and corresponding external and internal loads as well as detailed stress analyses. Since the goal of the baseline analysis was to determine the amount of damage accumulated while under USN usage, the evaluation consisted of developing mission profiles based on the FAA approved NAVAIR flight manual and performance parameters as stipulated on the FAA Type Certificate. Note that all USFS airtanker operations of the P2V are performed under "public use" and are therefore not considered under FAA jurisdiction while performing that role. Only those operations outlined in the NAVAIR flight manual along with any restrictions are considered applicable to this phase.

FAA REQUIREMENTS

Although the P2V was originally certified by the USN, the aircraft employed by the operators are regulated by the FAA and the corresponding Type Certificate. As a surplus US military aircraft, the P2V was certified by the FAA under Part 21 requirements. The type certificate for the P2V was awarded based on the prior USN certification and corresponding flight and maintenance documents as well as its prior service history. The type certificate also specifies the types of operations for which the aircraft is approved. Recently however, the FAA has reviewed its prior requirements for awarding restricted category type certificates and is in the process of producing new regulations which expand those requirements further. The following is an excerpt from a draft version of the new order 8110.RC:

> *"The applicant must determine the limitations for safe operation. This evaluation must include a structural analysis of loads and fatigue in the mission operating environment. The applicant must also determine the life limits of fatigue-critical and fatigue-sensitive components. When developing operating limitations, the operational assumptions used in the loads and fatigue analysis and any tests must be considered." "The applicant must determine and include all life limits and mandatory inspections in the airworthiness limitations section of the maintenance manuals."*

Based on the previous FAA and NTSB recommendations as well as the latest available draft information regarding restricted category aircraft, the baseline evaluation of the P2V was performed in accordance with the latest FAA requirements. The basic FAA requirements used in the P2V evaluation are those contained in FAR 25.571. FAA Advisory Circulars AC 25.571-1C and AC 91-56B were also utilized. The technical requirements of the FAR's and the AC material is essentially industry standard however the actual scope and process of the structure evaluated and the resulting inspection requirements and/or modifications developed are quite different than those employed in US military evaluations.

The basic source of the difference between FAA and military requirements essentially stems from the different roles they each play in the development and sustainment of an aircraft. The FAA F/DT NRS Mr. Robert Eastin presented a detailed comparison of the differences at the ASIP 2005 Conference. As a summary, the following list presents a general comparison of the differences.

FAA Type Certificated Aircraft

- TCH develops design to market demands and to meet FAA requirements
- FAA supports and certifies TCH design
- Operator owns and maintains aircraft to FAA requirements
- Operator or Independent Maintenance facility maintains aircraft to FAA requirements

Military Certificated Aircraft

- Military specifies design and build requirements to OEM
- Military certifies and owns aircraft
- Military operates aircraft
- Military maintains aircraft

Based on the above, it is evident that the FAA's requirements regarding structural integrity would certainly result in a different implementation than that employed by the military since they do not control the design, build specifications, operations or maintenance of the airplane. As such, the FAA requirements essentially regulate to the lowest common denominator, the operator and/or maintainer. The FAA ensures that any new design must posses design features which are safe and free of widespread fatigue damage (WFD) and that damage tolerance based inspections be provided for all principle structural elements (PSE) of the airframe to the operators to ensure the safe continued airworthiness of the airframe for the entirety of its service life with typically no further interaction between them and the operator/maintainer required unless service history indicates otherwise. There are currently no aircraft design level requirements for life limitations or operational service lives. The FAA places the responsibility on the type certificate holder (TCH) and operator to ensure the safe continued airworthiness of the airframe for as long the aircraft is operated.

The above cited FAA requirements had a direct impact to the actual process and outcome of the following tasks being performed as part of the P2V evaluation.

- Analysis locations selected for both localized details as well as general acreage coverage in order to address the FAA requirements for identifying PSE
- WFD evaluations were performed utilizing FAA approved scatter factors
- Inspection frequencies were established for all PSE evaluated based on the indefinite operation of the aircraft
- Life limitations were set for local details with poor fatigue lives as well as those prone to WFD
- ICA developed for PSE inspections and replacement times for life limited components
- No service life limit is required so long as the aircraft is maintained to the FAA approved ICA

USFS REQUIREMENTS

The basic requirements set forth by the US Forest Service for the P2V evaluation were essentially twofold. First, a fully FAA approved evaluation and resulting ICA program was to be developed for the baseline operations of the P2V while under FAA operations. For operations under the USFS, an initial operational service life (OSL) was to be established for the entire airframe. This OSL is not required by the FAA but was to be developed based on the fatigue life limitations imposed by details susceptible to WFD for the baseline operations. Subsequently, the impact of the airtanker usage was to be accounted for by determining severity factors to be applied to both the ICA inspections and the OSL.

While the evaluation of the airtanker usage is still under way, the OSL for the baseline operations was determined. The resulting OSL was determined to be 15,000 flight hours. This is based on a WFD evaluation of the WS 192 center to outer wing chordwise splice. This OSL will be re-evaluated based on the airtanker usage and updated at a later date.

TEST AND SERVICE HISTORY

With the support of the US Forest Service, relevant test and substantiating reports as well as service history data were purchased from the Lockheed Martin Post Production Support Group in Greenville, SC. These reports assisted in providing reference data in establishing the previous design and service performance of the P2V airframe. Of particular note, a significant amount of US Navy service data was located which identified and documented areas with a past history of fatigue and corrosion damage previously unknown to the current operators. This data along with operator data was utilized in evaluating structural details for analysis. Some of the more significant service history data found are as follows:

- WS276 Jet Pod Attach Bolt Failures
- WS192 Spar Attachment Bolt Failures
- WS192 Spar Cap Splice Fitting Fatigue Cracks
- WS 84.5 Upper Cover Access Hole Fatigue Cracks

In addition, some component level fatigue test results were reviewed. These tests assisted in correlating WFD analyses since the components were tested to complete failure. In particular, the WS192 joint was tested and validated the analysis which indicated multi-site damage at the stringer to fitting attachments.

As previously mentioned, the Japanese Government was instrumental in locating and graciously donating plans and results for the full scale fatigue test of a P2V-5 airframe performed in Japan in 1968. Although the reports were not received until mid-way thru the program, the results of this test were instrumental in verifying the points chosen for analysis and in correlating analytical results to the test failures.

The full scale fatigue test was performed on ex-BUNO 124870 which was a P2V-5F model aircraft provided by the USN and shipped to Japan in 1966. Upon arrival in Japan, the test article was disassembled, inspected, repaired and had all necessary aircraft service changes incorporated. The airframe was further modified as much as possible to a P2V-7 configuration. The test article consisted of the full wing with tip tanks, fuselage carry thru structure, horizontal tail and landing gear.

The fatigue test was started in May 1968 and completed in March 1969. The test article had a total of 4371 flight hours and 1100 landings accumulated service history prior to testing. The full scale fatigue test applied an additional 12990 flight hours of spectrum loading for a total of 17361 flight hours on the article. The fatigue loads on the test article were supplied by the USN and consisted of Mil-8866 loadings for maneuver, gust, landing and taxi. The applied loads reflected a design gross weight of 67,500 lbs with a design limit load factor of 2.67g. Flight spectrum loading was applied in 60 flight hour blocks.

During testing, the test article received a detailed inspection every 900 flight hours. The majority of early cracking consisted of fixture items and secondary structure. The following is a listing major failures discovered during testing.

- At 2960 flight hours, wing attachment tension bolts were found cracked. Probable cause was identified as loss of torque due to removal of bolts for inspection.
- Main landing gear shock strut failed at 9733 flight hours due to a fatigue crack.
- Failure of wing rear spar web occurred at 12670 flight hours. Fatigue cracks developed at satellite holes adjacent to web cutout on LHS & RHS wings resulting in spar web failure and subsequent spar cap and attachment bolt failures at WS 215.

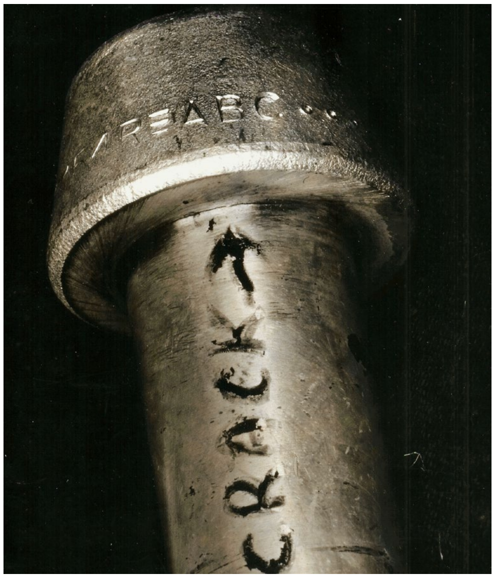


Figure 3 View of Cracked Tension Bolt

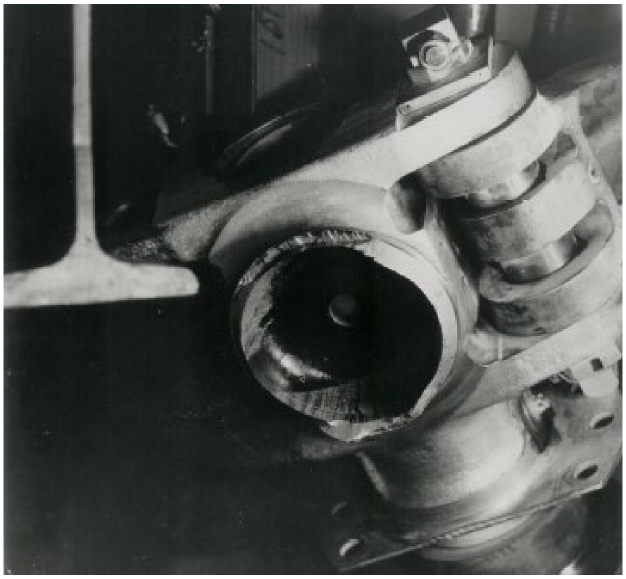


Figure 4 View of Fatigue Failure at MLG Strut Radius

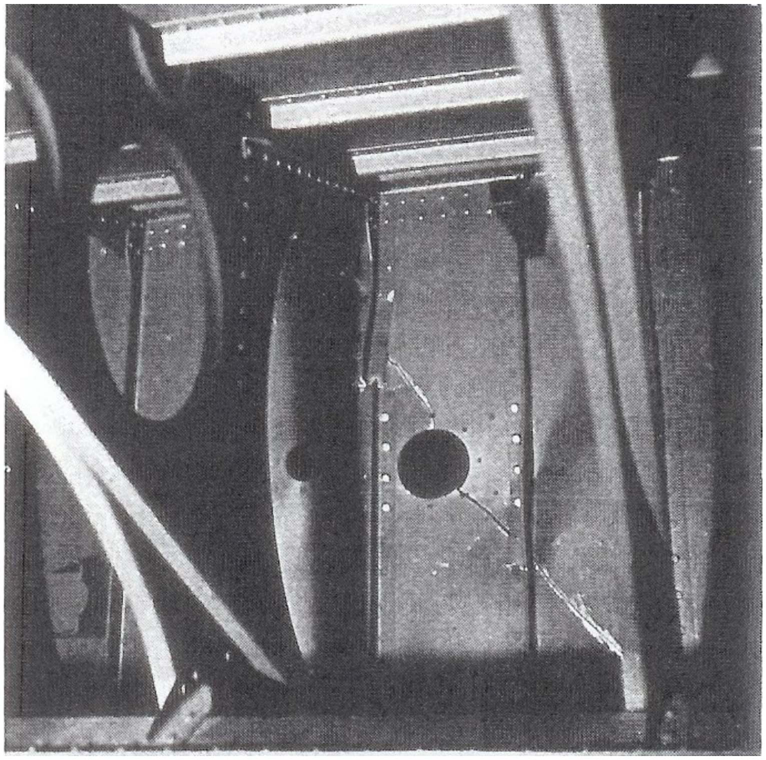


Figure 5 View from trailing edge of wing at WS 215 rear spar web failure

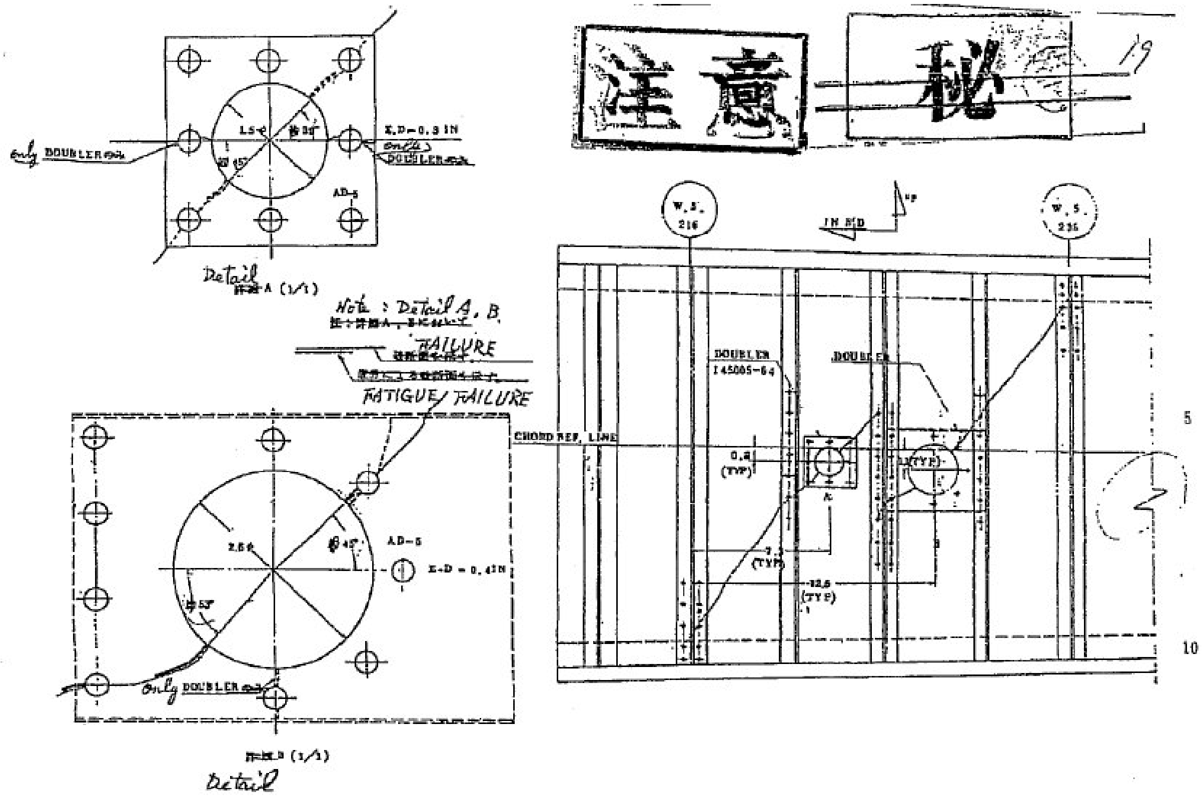
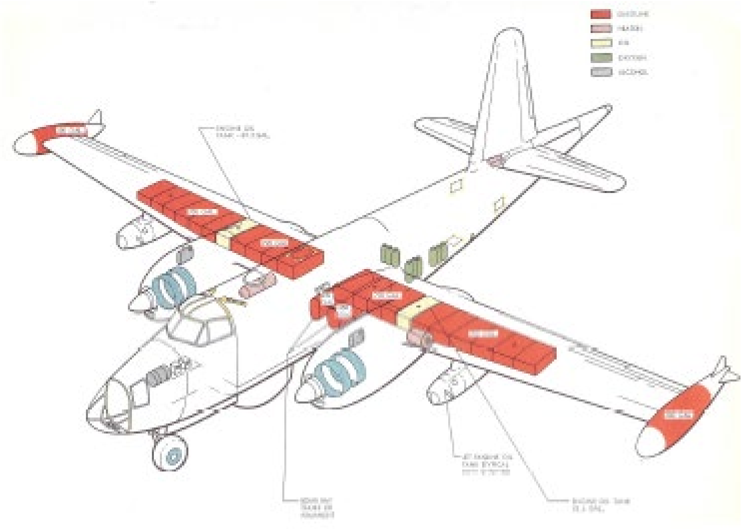


Figure 6 Details of WS215 Spar Web Failures during JMSDF Full Scale Fatigue Test

MISSION AND USAGE DEVELOPMENT

The first task in the evaluation was to determine the baseline configuration and to establish the process by which the mission profiles and corresponding flight segments were developed. The aircraft configuration selected was that for which the FAA TCDS A17EA was awarded being a P2V-5F. However, since the goal of the baseline analysis is to evaluate the USN prior usage, the TCDS configuration was augmented by assuming any USN wing stores as well as the installation of tip pods. In addition, upon researching each of the P2V aircraft utilized by the USFS in the airtanker role it was discovered that all were originally configured as anti-submarine warfare (ASW) aircraft while in the service of the USN. Therefore, the baseline configuration selected was one that reflects the aircrafts prior ASW role.



Jet Pod Equipped P2V-5 and P2V-7

Maximum Take Off Gross Weight = 80,000 lbs

Maximum Landing Weight = 59,000 lbs

Design Zero Fuel Weight = 56,050 lbs

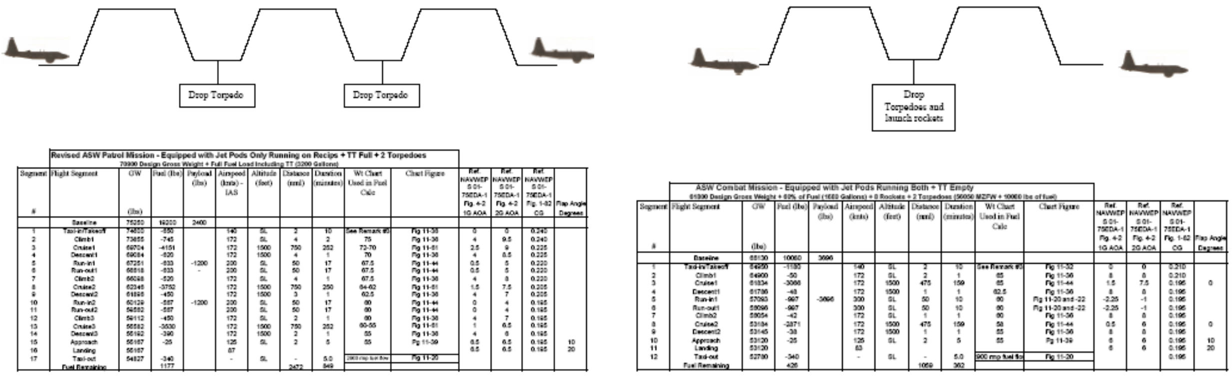
Maximum Dive Speed, VD = 350 knots

Maximum Level Flight, VH = 340 knots

Design Load Factors = +2.67 and -1.0

Figure 7 Aircraft Configuration

Based on available USN service usage history, the ASW configuration, the NAVAIR flight manual, and even information from prior flight crew members, baseline mission profiles were established. In order to develop the corresponding flight segments, the aircraft and engine performance data as well as the fuel burn rates from the flight manual were utilized. The method was correlated to parameters previously developed for design conditions and compared favorably. Essentially two ASW baseline mission profiles were developed. The utilization rates of each were based on USN service history.



Revised ASW Patrol Mission - Equipped with Jet Pods Only Running on Recips + TT Full + 2 Torpedoes
70900 Design Gross Weight + Full Fuel Load Including TT (3200 Gallons)

Segment #	Flight Segment	GW (lbs)	Fuel (lbs)	Payload (lbs)	Airspeed (knts) - IAS	Altitude (feet)	Distance (nml)	Duration (minutes)	Wt Chart Used in Fuel Calc	Chart Figure	Ref. NAVWEP S 01-75EDA-1 Fig. 4-2 1G AOA	Ref. NAVWEP S 01-75EDA-1 Fig. 4-2 2G AOA	Ref. NAVWEP S 01-75EDA-1 Fig. 1-82 CG	Flap Angle Degrees
	Baseline	75250	19200	2400										
1	Taxi-in/Takeoff	74600	-650		140	SL	2	10	See Remark #3	Fig 11-36	0	0	0.240	
2	Climb1	73855	-745		172	SL	4	2	75	Fig 11-36	4	9.5	0.240	
3	Cruise1	69704	-4151		172	1500	750	252	72-70	Fig 11-61	2.5	9	0.225	
4	Descent1	69084	-620		172	1500	4	1	70	Fig 11-36	4	8.5	0.225	
5	Run-in1	67251	-633	-1200	200	SL	50	17	67.5	Fig 11-44	0.5	5	0.220	
6	Run-out1	66618	-633	-	200	SL	50	17	67.5	Fig 11-44	0.5	5	0.220	
7	Climb2	66098	-520		172	SL	4	1	67.5	Fig 11-36	4	8	0.220	
8	Cruise2	62346	-3752		172	1500	750	250	64-62	Fig 11-61	1.5	7.5	0.205	
9	Descent2	61896	-450		172	1500	3	1	62.5	Fig 11-36	4	7	0.205	
10	Run-in2	60129	-567	-1200	200	SL	50	17	60	Fig 11-44	0	4	0.195	
11	Run-out2	59562	-567		200	SL	50	17	60	Fig 11-44	0	4	0.195	
12	Climb3	59112	-450		172	SL	2	1	60	Fig 11-36	4	7	0.195	
13	Cruise3	55582	-3530		172	1500	750	252	60-55	Fig 11-61	1	6.5	0.195	
14	Descent3	55192	-390		172	1500	2	1	55	Fig 11-36	4	6	0.195	
15	Approach	55167	-25		125	SL	2	5	55	Fig 11-39	6.5	6.5	0.195	10
16	Landing	55167			87						6.5	6.5	0.195	20
17	Taxi-out	54827	-340		-	SL	-	5.0	2900 rmp fuel flow	Fig 11-20				
	Fuel Remaining		1177				2472	849						

ASW Combat Mission - Equipped with Jet Pods Running Both + TT Empty
61000 Design Gross Weight + 60% of Fuel (1680 Gallons) + 0 Rockets + 2 Torpedoes (56050 MZFW + 10080 lbs of fuel)

Segment #	Flight Segment	GW (lbs)	Fuel (lbs)	Payload (lbs)	Airspeed (knts)	Altitude (feet)	Distance (nml)	Duration (minutes)	Wt Chart Used in Fuel Calc	Chart Figure	Ref. NAVWEP S 01-75EDA-1 Fig. 4-2 1G AOA	Ref. NAVWEP S 01-75EDA-1 Fig. 4-2 2G AOA	Ref. NAVWEP S 01-75EDA-1 Fig. 1-82 CG	Flap Angle Degrees
	Baseline	66130	10080	3696										
1	Taxi-in/Takeoff	64950	-1180		140	SL	2	10	See Remark #3	Fig 11-32	0	0	0.210	
2	Climb1	64900	-50		172	SL	2	1	65	Fig 11-36	8	8	0.210	
3	Cruise1	61834	-3066		172	1500	475	159	65	Fig 11-44	1.5	7.5	0.195	0
4	Descent1	61786	-48		172	1500	1	1	62.5	Fig 11-36	8	8	0.195	
5	Run-in1	57093	-997	-3696	300	SL	50	10	60	Fig 11-20 and -22	-2.25	-1	0.195	
6	Run-out1	56096	-997		300	SL	50	10	60	Fig 11-20 and -22	-2.25	-1	0.195	
7	Climb2	56054	-42		172	SL	1	1	60	Fig 11-36	8	8	0.195	
8	Cruise2	53184	-2871		172	1500	475	159	58	Fig 11-44	0.5	6	0.195	0
9	Descent2	53145	-38		172	1500	1	1	55	Fig 11-36	8	8	0.195	
10	Approach	53120	-25		125	SL	2	5	55	Fig 11-39	6	6	0.195	10
11	Landing	53120			83						6	6	0.195	20
12	Taxi-out	52780	-340		-	SL	-	5.0	900 rmp fuel flo	Fig 11-20			0.195	
	Fuel Remaining		426				1059	362						

Figure 8 Baseline Mission 1 and Mission 2 reflect past USN ASW Usage

ANALYTICAL METHODS

Due to the lack of any prior fatigue analysis on the P2V, methods for developing both external and internal fatigue loads had to be developed as well as a spectrum generation process. The methods employed were those previously developed by AAS but required tailoring for the specifics of the P2V.

EXTERNAL LOADS

The external loads development was performed utilizing linear steady state aerodynamics. Having access to existing structural weight distributions and aerodynamic coefficients and parameters, the external wing and empennage loads were developed for each of the baseline mission profile flight segments. Figure 9 depicts a plot of 1.0 g wing bending moments for all of the flight segments in Mission 1 of the USN navy usage profile for the P2V. Moments for two design limit load conditions are plotted for comparison. The variations in the various 1.0 g wing bending moments is due to changes in weight distribution as a result of fuel consumption and payload (wing stores).

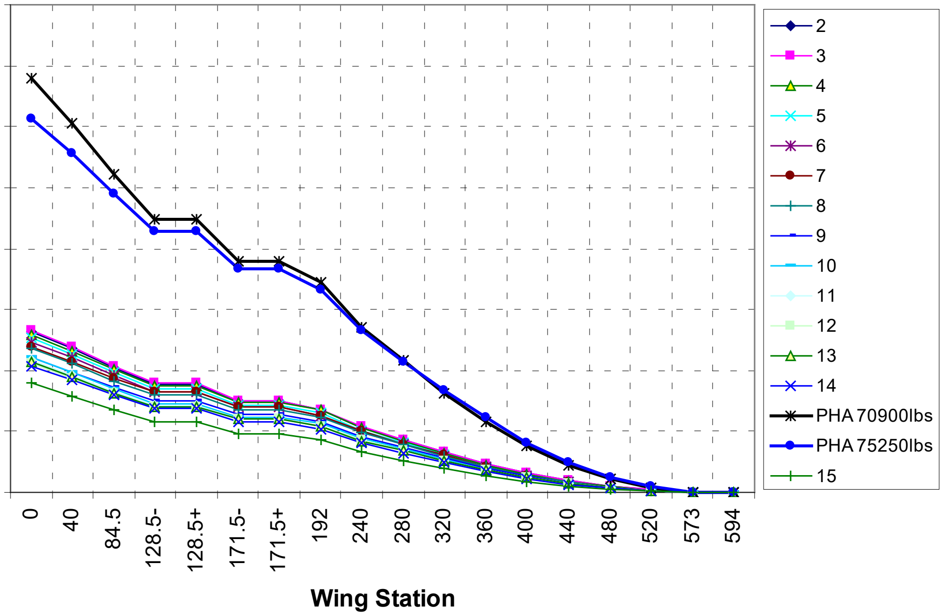


Figure 9 P2V-5/-7 One-g Wing Bending Moment Mx Distributions

INTERNAL LOADS

The method utilized in developing the internal wing load distributions was essentially the same as that used in the original analysis of the P2V except that it is a modern computerized version developed by AAS. The basic methodology employed in the original structural analysis of the P2V wing was the Lockheed unit beam method. This method was developed by F. R. Shanley and F.P Cozzone of the Lockheed Aircraft Corporation and was published in the Journal of Aeronautical Sciences in 1940. This method was used by the Lockheed Corporation for many years on all of the major airframes of the time period including the Constellation and P3 Orion.

The AAS computer program BoxBeam incorporates all of the unit beam methodology with added capabilities for applied loads conditions, wing stations, geometry and output. The entire method was modified to accommodate the P2V wing configuration and was correlated and validated against original design analysis conditions as well as original test results and recent data from currently instrumented aircraft.

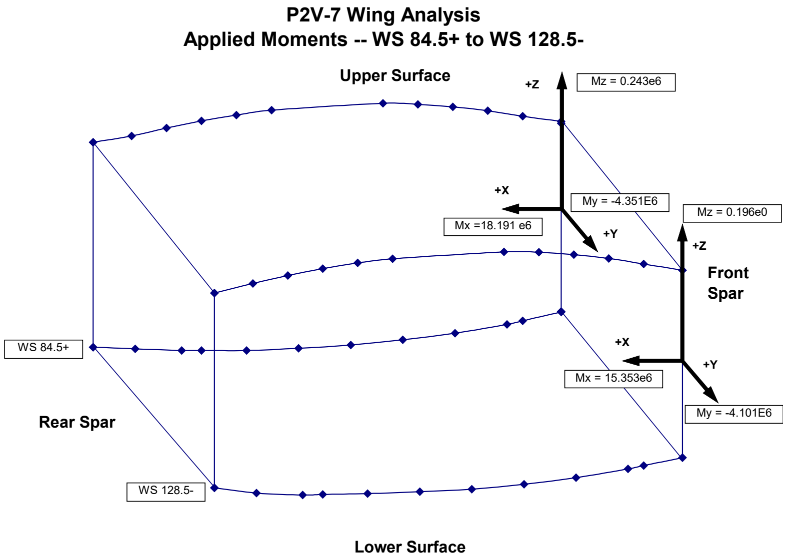


Figure 10 AAS BoxBeam Input Geometry Points and Applied Loads

Mode	P2V-7 Result	BOXBEAM Result	Percent Deviation
X-bar	33.599	33.599	0
Z-bar	0.8416	0.8413	0
Ix	5004.9	5004.8	0
Iz	16257	16258	0
Ixz	-893.68	-893.29	0

Table 2 – P2V Wing Station 128.5 Section Property Comparison to Original Design Values

Element	P2V-7 Original Stress Value	BOXBEAM Stress Value	Percent Deviation
1 – Up FS	-29140	-29148	0.0
2	-31956	-31962	0.0
3	-34710	-34716	0.0
4	-36906	-36912	0.0
5	-38574	-38581	0.0
6	-39873	-39877	0.0
7	-40424	-40429	0.0
8	-39584	-39586	0.0
9	-38524	-38527	0.0
10	-37062	-37064	0.0
11	-35259	-35261	0.0
12 – Up RS	-33981	-33983	0.0
13 – Lwr RS	35272	35276	0.0
14	36999	37003	0.0
15	38805	38809	0.0
16	41179	41182	0.0
17	41828	41831	0.0
18	41239	41241	0.0
19	40867	40867	0.0
20	39936	39935	0.0
21	38322	38322	0.0
22 – Lwr FS	35493	35492	0.0

Table 3 AAS BoxBeam Internal Loads Results Comparison to Original Design Values

SPECTRUM DEVELOPMENT

The methods utilized in developing the fatigue stress spectra for the P2V were developed by AAS and combine the internal loads output from BoxBeam with the mission profiles and corresponding load histories to produce complete flight by flight cycle by cycle stress spectra. The following components are utilized in developing the stress spectra.

- Load Histories
- Mission Definition
- Stress to Load Factors

Load Histories

Since fatigue was not a requirement during the original design of the P2V, no existing reference data was available regarding the P2V. Therefore, the histories contained in Mil-8866 were chosen for all sources such as maneuver, landing and taxi with the exception of gust. Since historical records indicated that the entirety of the P2V mission was performed at low altitudes, actual recorded data (primarily NACA low altitude data which includes clear air and storm turbulence) from similar configured aircraft of the time period were utilized. In fact, upon conferring with the FAA, even current commercial data was not deemed suitable as most of the current low altitude data is only recorded while the aircraft is climbing to altitude. As a note, upon receiving the full scale fatigue test plans from the Japanese government, it was verified that the test also employed Mil-8866 for its spectrum loading.

Maneuver

According to MIL-8866, since the P2V was considered a land based Anti-Submarine Warfare aircraft, the Type C maneuver spectra was chosen. This spectra is in terms of incremental load occurrences of limit load per 1,000 flight hours. The P2V design vertical limit load factor is 2.67 Nz. As such, the Mil-8866 percent of maximum load factor were applied to an Nz of 2.67 to develop the necessary load history occurrences.

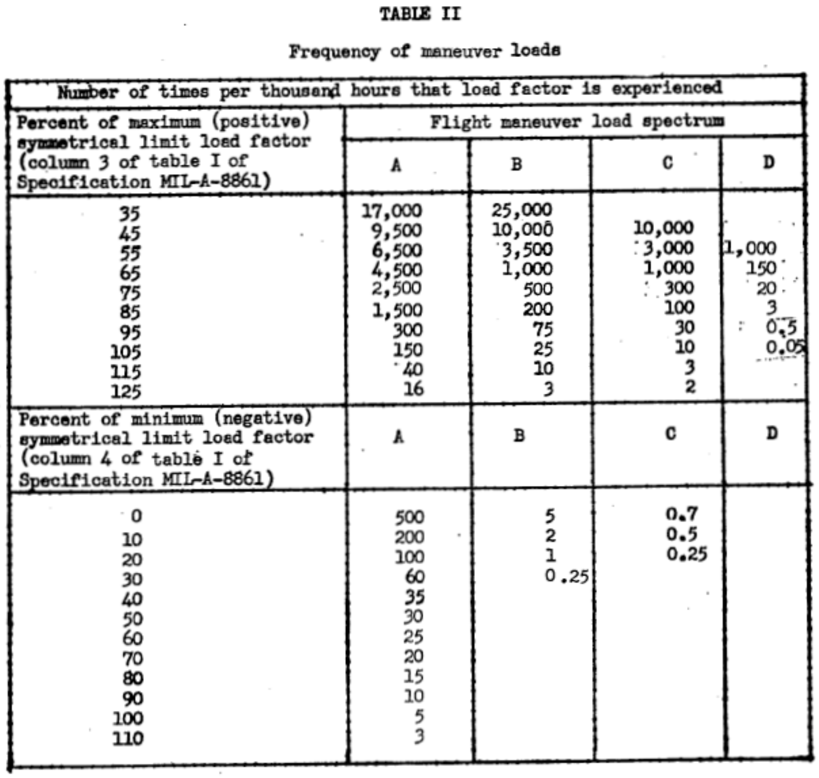


TABLE II

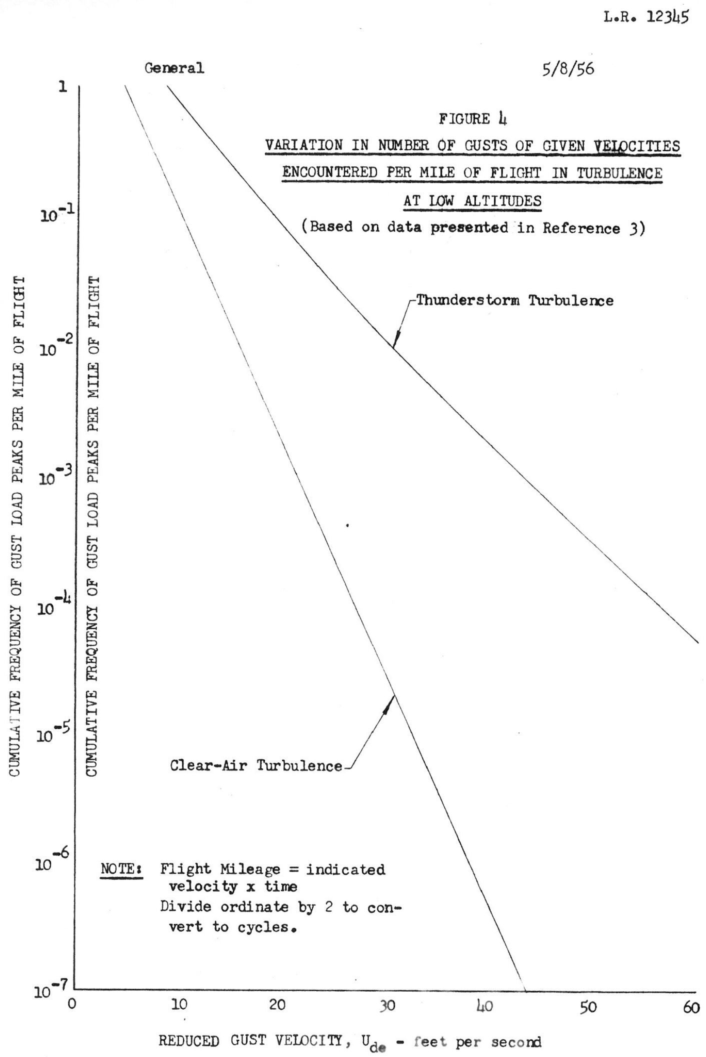
Frequency of maneuver loads

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
35	17,000	25,000		
45	9,500	10,000	10,000	
55	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			

Table 4 Mil-8866 Table II Depicting Maneuver Load Spectra

Gust

In order to provide a more representative gust spectrum for the P2V which reflected both its prior operational usage and lack of gust avoidance equipment, actual gust load histories from similar twin piston engine aircraft of the time period operating at low (0 to 5,000 feet) altitudes were utilized. This data was deemed more applicable to the P2V since it is based on similarly configured aircraft and presents a large amount of cruise data at low altitudes which is absent in more current operational load histories. The data utilized was obtained from NACA TN-2663 and from Lockheed LR 12345. This report evaluates and envelopes the recorded NACA gust data and was utilized by Lockheed for the fatigue evaluation of various aircraft.



L.R. 12345

General

5/8/56

FIGURE 4

VARIATION IN NUMBER OF GUSTS OF GIVEN VELOCITIES ENCOUNTERED PER MILE OF FLIGHT IN TURBULENCE AT LOW ALTITUDES

(Based on data presented in Reference 3)

NOTE: Flight Mileage = indicated velocity x time
Divide ordinate by 2 to convert to cycles.

Figure 11 Figure 4 of Ref. 19 Depicting Low Altitude Clear Air and Storm Turbulence

Landing and Taxi

The load histories used for both of these sources were obtained from Mil-8866 as well. In order to account for the non-linear response of the wing due to these sources (particularly due to the effects of the tip pods), dynamic magnification factors were employed. These were developed from recorded flight test data for both landing and taxi. The dynamic factors were thus developed for each wing station and applied during the spectrum development process.

Mission Definition

The flight segment sequence for each of the two missions is input into the spectrum program in terms of duration. Each of the segments uses specific identifiers to relate them to the load histories so that the correct alternate load pairing is performed. This is true for all segments with the exception of landing. Landing is accounted for in the spectrum as a discrete event based on actual recorded data. As a discrete event, a set number of cycles are prescribed for each landing rather than being randomly selected from a load history table.

Stress to Load Factors

For each of the specified flight segments in the spectrum input file, corresponding stress to load ratios are input. These ratios basically consist of the mean stress per 1g factor as well as the alternating stress per 1g factor. The ratios are obtained from the BoxBeam output results in terms of either axial or shear load or stress for a given element location and wing station.

Once all of the above data is compiled into the input for a given location, the spectrum is developed at a specific location. The flight by flight spectrum is developed in terms of a 1000 flight hour block consisting of a total of 160 flights of Mission 1 and Mission 2 fully randomized. As an example, Figure 14 depicts a single flight of the fatigue spectrum developed for Stringer 18 at WS 192. The WS 192 joint is the center to outer wing splice and stringer 18 is located on the lower wing cover.

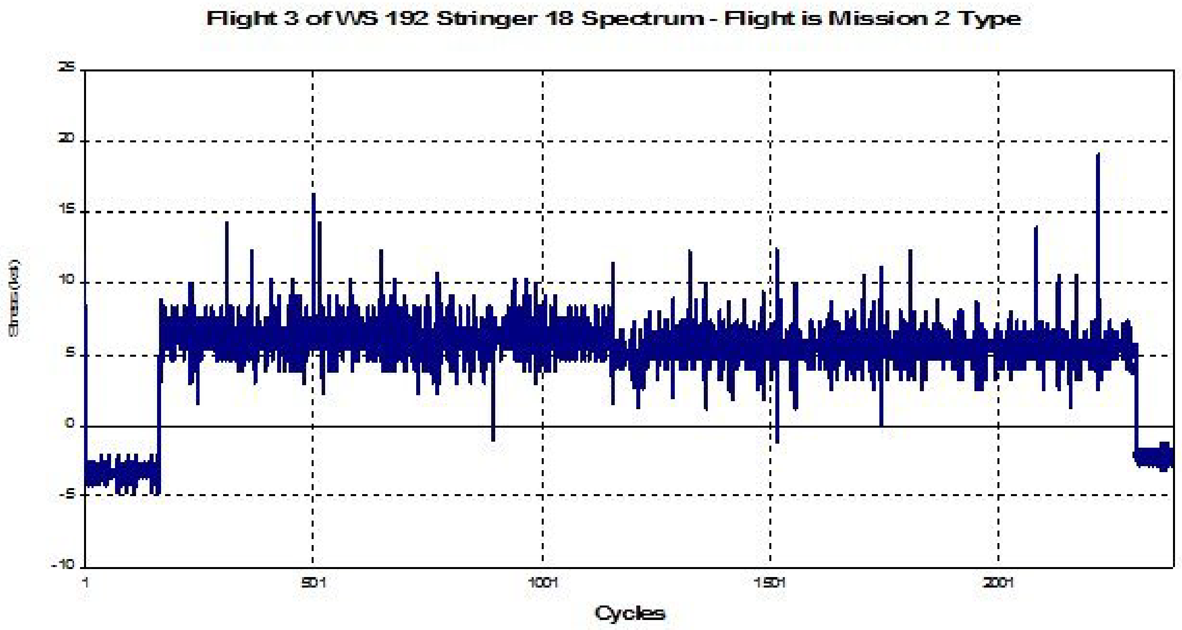


Figure 12 Flight 3 Stress Spectrum for Stringer 18 at WS 192

FATIGUE ANALYSIS (Crack Initiation)

The main purpose for performing a fatigue analysis of the basic wing and tail structure was focused at evaluating the structures fatigue life as well as its susceptibility to widespread fatigue damage (WFD). As with any fatigue analysis, the basis of that analysis will be the geometric factors which drive the stress concentration at the detail of interest and the calculation of the accumulation of damage via a computerized tool using material data that defines the material's susceptibility to crack initiations.

The basic methodology employed for the P2V crack initiation analysis consisted of the AAS modified version of the standard industry Stress Severity Factor (SSF) methodology and of Program FLIP (Fatigue

Load Interaction Program), an AAS version of the sequence accountable fatigue analysis program (SEAFAN). These standard methods were significantly modified by AAS to incorporate fatigue coupon and component test results to more accurately estimate the fatigue life of the structure and results from each were correlated with both constant amplitude and flight by flight spectra to ensure the accuracy of the calculations.

With respect to SSF, a significant amount of industry joint test data was utilized in developing appropriate alpha and beta correction factors, which account for the hole condition and the 'hole filling' effects of the fasteners being utilized. These factors, such as bearing stress concentration factors and open hole stress concentration factors are combined to define the overall stress concentration of the detail of interest.

With respect to the Program FLIP, joint fatigue test data curves were actually reduced such that they could be utilized within the program for the applicable wing and empennage materials. The program utilizes the fatigue spectrum calculated, along with the stress concentration factor and other material growth data to calculate the overall fatigue life of the detail being analyzed by summing the fatigue damage for each load cycle being seen. The purpose behind using a program such as one that accounts for load sequencing is the fact that many stresses in the P2V wing flight envelope are of such a level that they could cause yielding of the structure when the stress is combined with the relative stress concentration at the area of interest. Overloads such as this tend to impact the onset of fatigue damage for a subsequent number of following stress cycles because of the yielding of the material locally at the detail of interest. Analysis that could have been accomplished without taking this yielding phenomenon into consideration would have proven to be not representative and would not have correlated in any large manner to the tests that were conducted on the P2V wing structure. Utilizing this load sequencing technique proved to be more accurate and greater correlation to existing test data was obtained by its use.

CRACK GROWTH ANALYSIS

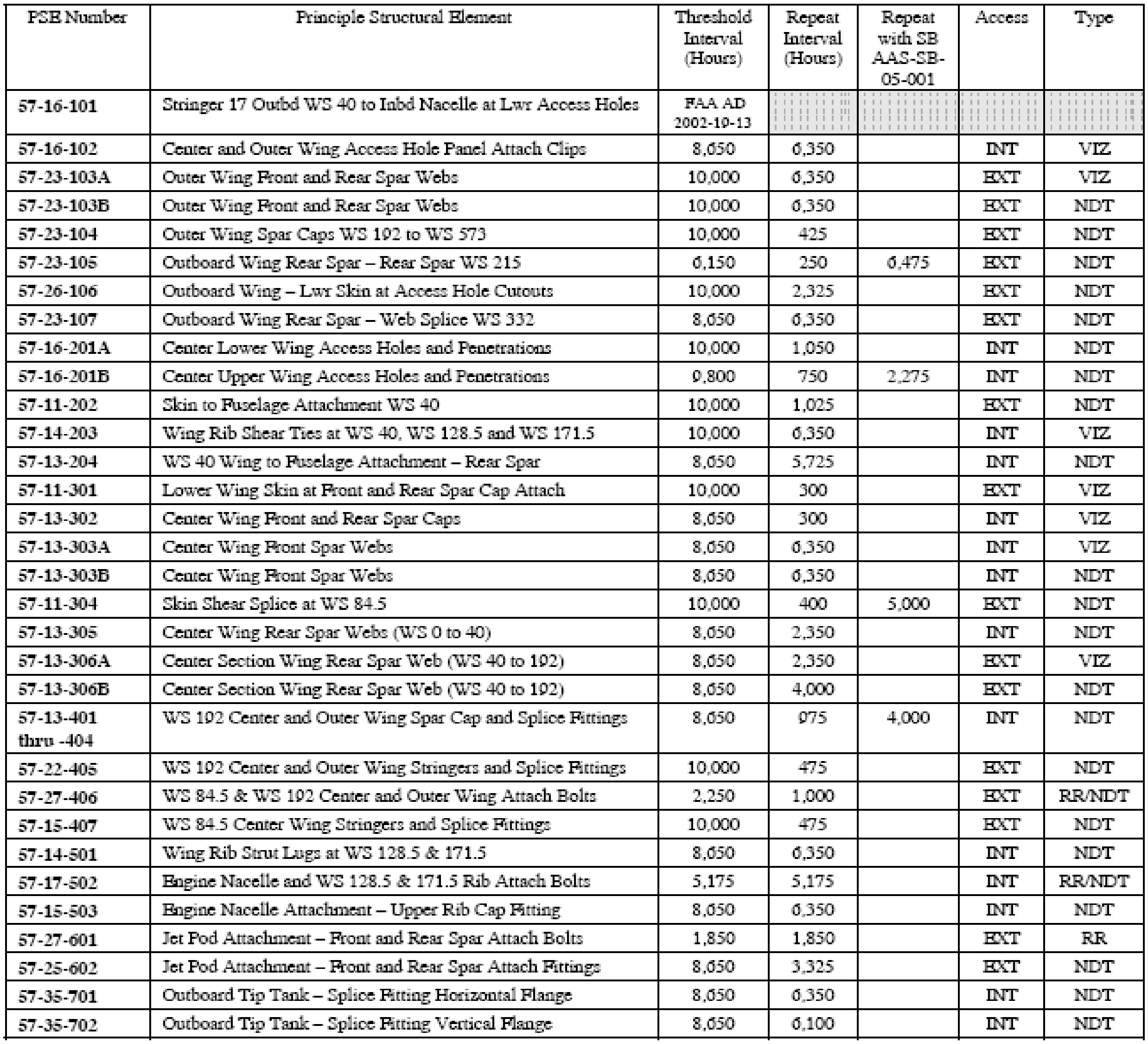
The main purpose of performing crack growth analysis was to establish damage tolerance based inspections for all wing and empennage Principle Structural Elements (PSEs). For this project, the crack growth software employed was the University of Dayton Research Institute’s Cracks2k. This program utilizes common industry data (such as its NASGRO material database as well as other industry sources) to calculate the growth of flaws due to spectral loading. In addition to those contained in Cracks2k, several industry stress intensity solutions for both localized details and large scale stiffened panel solutions were utilized. Cracks2k results are utilized, along with inspection parameters such as detectable flaw sizes, to calculate inspection intervals and establish reliable methods for finding damage before it reaches critical sizes on all pieces of structure who's loss could cause loss of the airplane en masse.

FAA ICA DEVELOPMENT

The development of the ICA was an intensive task which combined the development of inspection procedures accounting for detectability and access requirements. The ICA itself is comprised of multiple sections which present the following material for use by the operators:

- Airworthiness Limitations Section
    - Component Life Limits
    - PSE Inspection Thresholds and Frequency Requirements
- Reporting Requirements
- Inspection Methods and Criteria
- Visual Inspection Procedures
- NDT Inspection Procedures

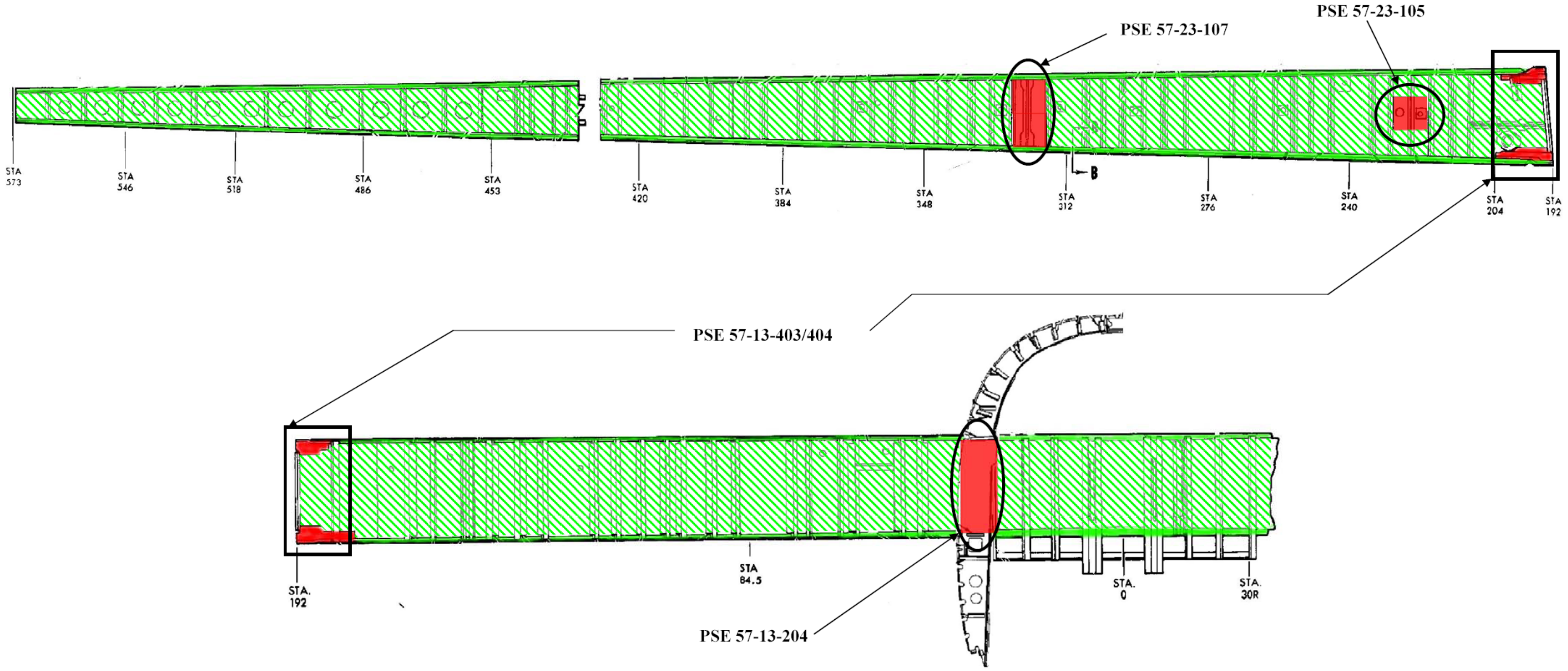
As an example, the following table presents the summary of PSE inspections requirements from the Airworthiness Limitations Section of the P2V FAA ICA.



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 5 P2V Airworthiness Limitations Section Containing PSE Inspection Frequencies

As noted earlier, the FAA requirements regarding continued airworthiness dictate that all portions of PSE have damage tolerance based inspections to include both local details as well as general acreage. As a result, the number of analysis locations and corresponding inspection requirements can be significant. For example, the rear spar of the P2V is categorized for obvious reasons as well as test evidence as a PSE. As such, inspections were developed for both local details such as splices as well as for the general acreage. Figure 13 below illustrates the extent of inspections specified in the ICA for the rear spar.



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

Figure 13 P2V PSE Inspections for Rear Spar

INSPECTION FINDINGS TO DATE

At the time of writing this paper, the inspections and replacements contained in the P2V ICA have been completed fully on 1 aircraft while 3 other aircraft are currently in work. Several fatigue cracks were found as part of the ICA inspections which were not previously detected thru the normal maintenance procedures contained in the P2V NAVAIR Maintenance Manual. The major results of the inspection findings to date are as follows:

- Fatigue Crack (approx 0.75") found at WS215 Rear Spar Web Cutout
- Fatigue Crack (approx 0.015") found at WS192 Spar Cap Splice
- Fatigue Crack (approx 1.5") found at WS74 Upper Wing Panel Access Hole #2
- Stress Corrosion Crack (approx 4") found at WS192 Front Spar Cap Splice

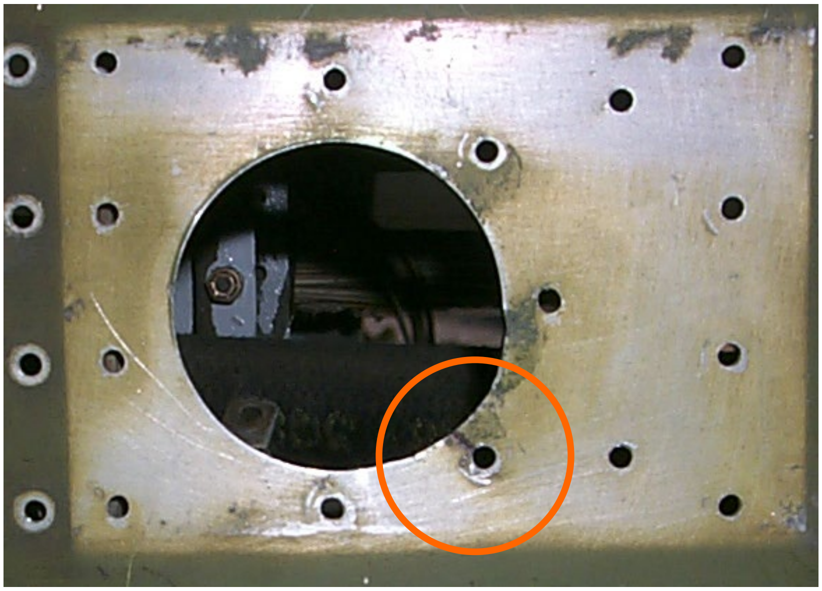


Figure 14 Depiction of Fatigue Crack found in Rear Spar Web at WS 215

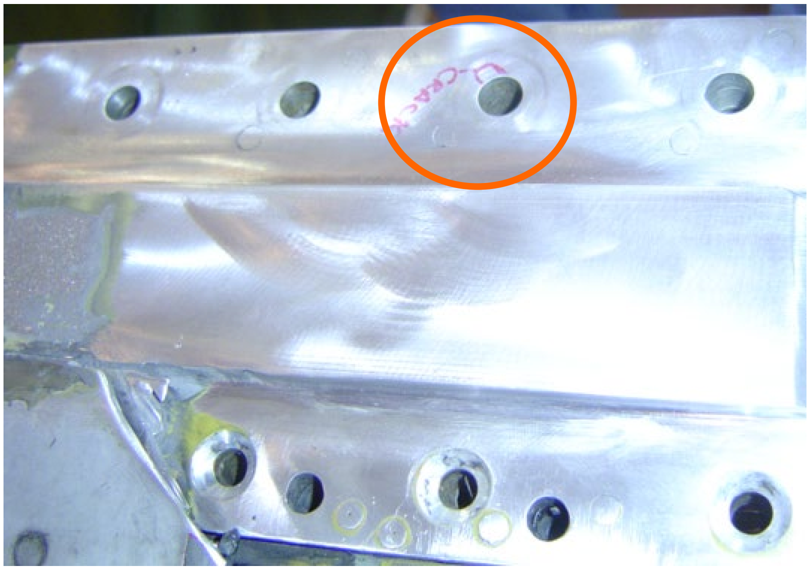


Figure 15 Depiction of Fatigue Crack found in Bolt Hole of Spar Cap at WS192 Splice

DETERMINATION OF USFS OSL

The USFS established a requirement separate from the FAA for an operational service life limit (OSL). The basis of this OSL is established by the PSE demonstrating the lowest fatigue life resulting from WFD. With respect to the P2V, following a complete evaluation of the wing and empennage, it was determined that the WS 192 wing joint demonstrated the lowest fatigue life due to WFD. As such, a USFS OSL was established for the baseline evaluation at 15,000 flight hours. Comparing this to the current status of the fleet (see Figure 16), no airtanker to date has over-flown the baseline USFS OSL.

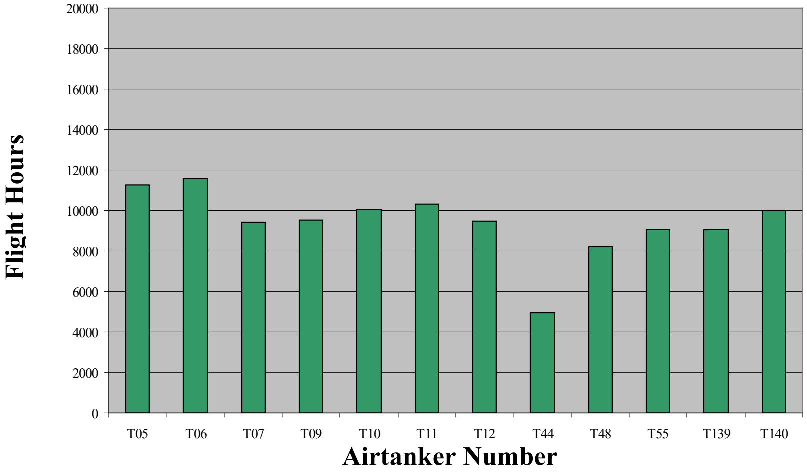


Figure 16 Status of USFS Airtanker Fleet

In support of the USFS OSL, a service bulletin (SB) was developed for all areas which demonstrated poor fatigue lives at localized details not due to WFD. This Service Bulletin, AAS-SB-05-001, provides the necessary structural modifications to ensure the airframe meets the baseline OSL requirement. The areas found requiring modification are as follows:

- WS192 Spar Cap Joint
- WS215 Rear Spar Web Cutout
- Upper Wing Cover Access Holes

Figure 17 illustrates the SB reinforcement required at the WS215 Rear Spar Web Cutout. This reinforcement ensured the web was shear resistant and thereby eliminated a severe fatigue load source.

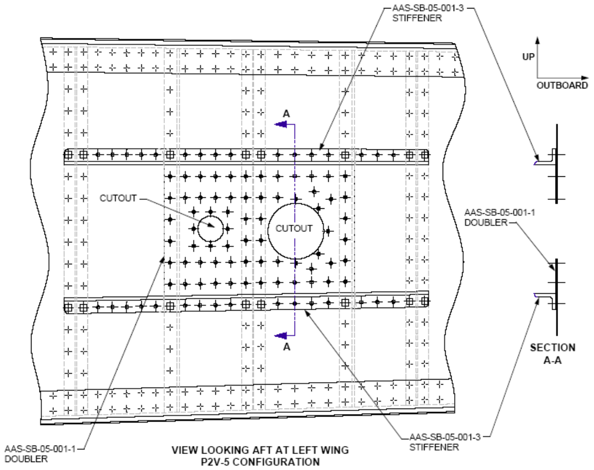


Figure 17 Depiction of AAS-SB-05-001 Structural Modification to WS215 Rear Spar Web

PHASE 2 – AIRTANKER EVALUATION

Having completed the baseline evaluation of the P2V wing and empennage in Phase 1, the evaluation of the impact due to the airtanker role is currently being performed under Phase 2. The objective of the evaluation is determine any impacts to both FAA PSE inspection requirements as well as the USFS OSL. The airtanker evaluation is currently being performed thru the use of recorded flight data. At present, two airtankers are fully instrumented and have collected data throughout the 2005 season. This is the main source of data for the present evaluation.

Figure 18 USFS P2V Airtanker Performing a Retardant Drop

INSTRUMENTATION AND RECORDED PARAMETERS

The instrumentation and parameters recorded on the airtankers consist of generic flight parameters, discrete flight parameters, and specific parameters. Samples of the more important generic and discrete parameters being recorded are contained in Tables 6 and 7.

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

Table 6 USFS Airtanker Recorded Generic Flight Parameters

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

Table 7 USFS Airtanker Recorded Discrete Flight Parameters

The more specific recorded parameters consist of strain gages selectively located at structural details throughout the wing and empennage. The locations were selected based on previously correlated points as well as areas of criticality. Table 8 presents the locations and the type of strain gage employed.

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

Table 8 USFS Airtanker Specific Recorded Parameters

PILOT SUPPLEMENTAL DATA

To assist in obtaining some of the parameters not recorded thru instrumentation, the airtanker pilots complete a supplemental data form for each mission flown. Table 9 provides a sample listing of the items noted by the pilots on the supplemental data form. Note that the most important parameters recorded are those listing fuel weight, drop time, drop altitude, drop runs and coverage.

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			

Table 9 Sample of Airtanker Supplemental Data

EVALUATION OF RECORDED DATA

During the 2005 Airtanker season, the two instrumented P2V tankers collected at total of 451 flight hours worth of data. The data is currently being reviewed by AAS as part of the airtanker usage evaluation. The main use of the three types of recorded parameters discussed previously are as follows:

- Generic, Discrete and Supp. Data – Development of Airtanker Mission Profiles and Segments
- Generic Data – Load Histories
- Specific/Strain Data – Correlation and Validation of Airtanker Loads Development

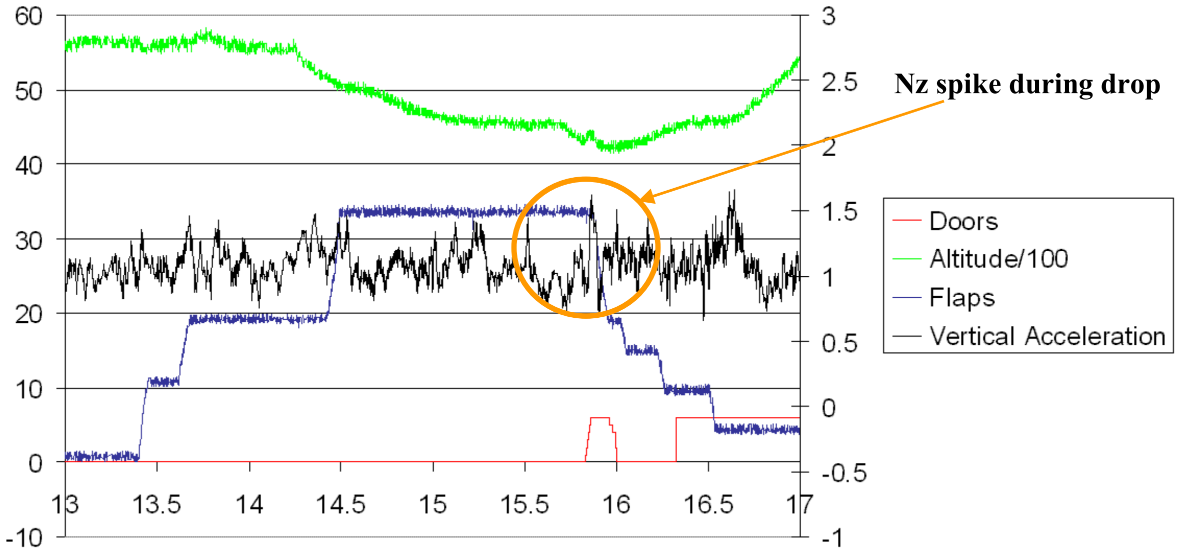


Figure 19 Sample Recorded Data for Airtanker Mission – Note Nz spike during Drop

DETERMINATION OF MISSION PROFILES

The total database of recorded flights from the 2005 season are currently being reviewed. Each of the flights is evaluated and compared to each other for trends in total gross weight, fuel weight, retardant weight, drop configuration, airspeed, flight control settings and duration. Thru the evaluation and comparison of each of the recorded flights, typical missions and corresponding flight profiles and segments are developed. A sample drop mission is illustrated in Figure 20.

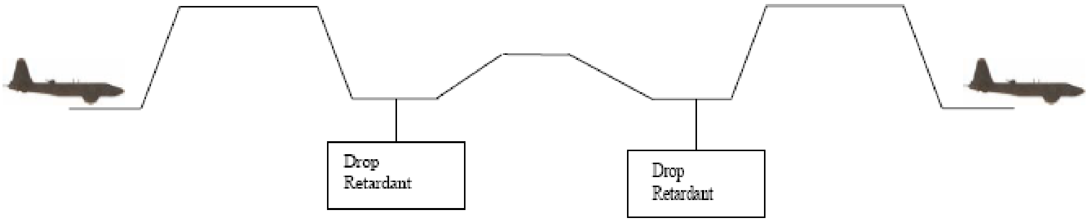


Figure 20 Typical Profile for an Airtanker Mission

EVALUATION OF LOAD HISTORIES

As a preliminary review of the data collected to date by both instrumented P2V aircraft, a summary of the total vertical accelerations recorded was made and normalized to a 1000 flight hour block. This summary of data was then compared to both the design curve used in the baseline analysis as well as a typical commercial aircraft design curve from literature. As can be seen in Figure 21, the recorded data to date falls below the design values utilized in the baseline evaluation an commercial transport recorded data. Note however, this is only for the limited data collected in 2005. As of yet, this is insufficient data to draw any particular conclusions regarding the severity of the airtanker usage and is merely presented to illustrate that the peak loads experienced by the instrumented aircraft during the 2005 season have not exceeded those in the design curve. A much larger database of recorded accelerations will be required in order to determine the actual severity of the airtanker role. For this reason, data will be collected for several years and continually evaluated.

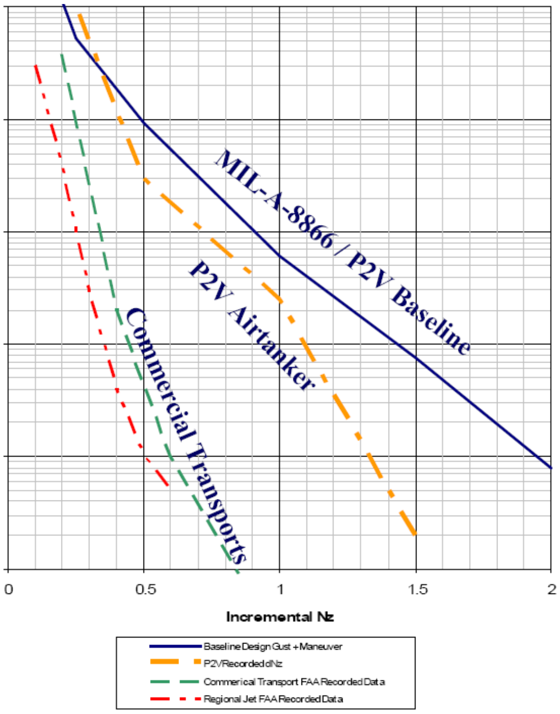


Figure 21 Comparison of Limited 2005 Airtanker Vertical Accelerations (Combined Gust+Maneuver)

EXTERNAL LOADS

The external loads for each of the mission profiles when established will be developed utilizing the same methodology as that employed in the Phase 1 baseline evaluation. However, of particular challenge, the drop segments of the mission will require a separate evaluation. This is primarily due to the large amount of payload dropped over a very short duration. In essence, an average payload of 18,000 lbs of retardant is dropped within a matter of seconds. The obvious impact to shift change in CG and resulting change in balancing tail loads must be evaluated. This is further complicated by the peculiar design of the P2V which includes an elevator and a Varicam. Essentially, the horizontal tail plane is articulated approximately mid-chord by the Varicam which acts like a large elevator and in turn the elevator performs as a large trim tab. The resulting change in CG due to the drop could have a significant impact on the function of this system and as such is currently being investigated.

AIRCRAFT CONFIGURATION AND WEIGHT DISTRIBUTION

The current configuration of the P2V aircraft employed in the airtanker role has some significant differences to that employed in the baseline evaluation. In general, all of the military electronics equipment and armaments are removed as well as some of the systems equipment. With respect to the wing, a significant amount of weight was eliminated thru the removal of the tip pods and the use of bladder fuel tanks in lieu of armored tanks. These two particular changes can have a significant impact on the inertia relief of the wing. In addition, the payload of the P2V includes the installation of the retardant tank and its content which is rated at a max capacity of 2700 gallons. As such, a complete weight and balance of the airtanker configuration was developed in order to develop accurate fatigue loads.

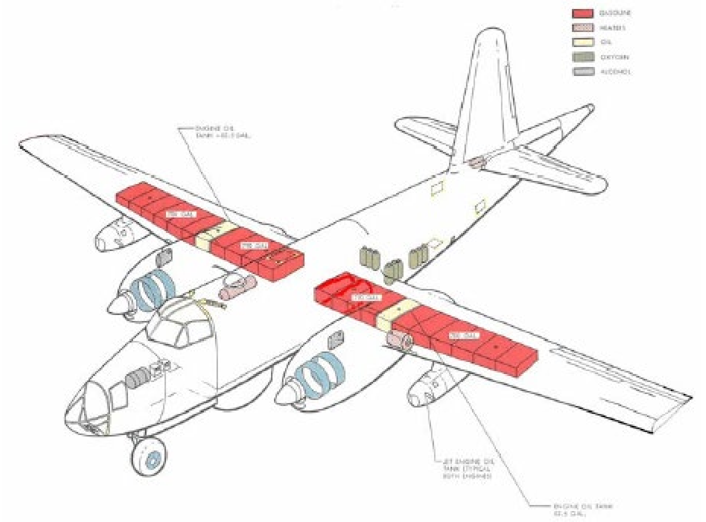


Figure 22 Airtanker Configuration without Tip Pods and with Fuel Bladders

ANALYSIS AND UPDATE OF INSPECTION CRITERIA AND OSL

Once the fatigue loads and spectra for the airtanker usage have been completely developed, each of the baseline PSE details will be re-evaluated. In addition, the structure will be examined for any new PSE requiring analysis as a result of the usage impact. Once the evaluation is complete, the existing baseline ICA will be reviewed. If necessary, a USFS update specifying any revised frequencies and/or additional inspection procedures will be published. In addition, the USFS OSL will be reviewed and re-evaluated for any resulting impacts from the airtanker usage.

PHASE 3 – CONTINUED TRACKING AND FLEET LIFE MANAGEMENT

To date, only one full season of recorded data exists for the P2V which is limited to approximately 450 flight hours of data. As a result, additional data is necessary in order to perform a full evaluation of the airtanker usage. Apart from the current two aircraft instrumented, it is the USFS's plan to fully instrument the remainder of the P2V fleet. This will ensure that a proper amount of data can be collected in order to define the airtanker usage. As a result, this evaluation will be revised in the future to take advantage of a much larger dataset.

In addition to the P2V fleet, the USFS operates many other aircraft in various roles. As such, the USFS is utilizing the current evaluation of the P2V as a prototype program for establishing a set of specifications and criteria for present and future USFS airtankers. It is intended, that all aircraft operating for the USFS have inspection programs based on the same methods and FAA requirements outlined for the P2V.

CONCLUSIONS

- Baseline F/DT Evaluation of the P2V Wing and Empennage Structure has been completed
- Baseline FAA Instructions for Continued Airworthiness for P2V completed
- FAA ICA is currently being incorporated by all P2V Airtanker operators
- P2V Airtanker fleet has not exceeded Baseline USFS OSL
- P2V Airtanker Recorded Usage Data is currently being evaluated
- Initial Airtanker Usage Evaluation is to be completed in 2006
- Additional P2V Airtankers are to be instrumented in 2006
- Airtanker Usage Recording to be continued throughout 2006 season and on.
- P2V Evaluation to be used by USFS for establishing Generic Airtanker Specifications

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