PROTOFLIGHT ENVIRONMENTS

FOR

BSAT-2 HYDRAZINE TANK

ATK P/N 80420-3

Table 1: P/N 80420-3 BSAT-2 Hydrazine Tank Assembly Specifications

Parameters	Requirements
Operating Pressure	400 psig
Proof Pressure	500 psig, Actual Proof: Not tested
Burst Pressure	600 pisg, Actual Burst: Not tested
External Pressure	Not Tested
Internal Vacuum	Not Tested
Material of Construction	Cylindrical Pressure Vessel constructed of 6AL-4V titanium. A vane type propellant management device (PMD) is provided to expel the fuel under low or zero gravity
Membrane Thickness	0.029″
Tank Mount(s)	Mounting is accomplished by struts attached to the polar bosses.
Expulsion Efficiency	%
Design Fill Fraction	-
Tank Capacity	9210 in^3
Internal Dimensions	22″ Ø x 32″
Tank Weight	Maximum tank weight is 17.8 lbs, Actual tank weight is lbs
Propellant Capacity	
Shell Leakage	$<1x10^{-6}$ std cc/sec He max, Actual:$x10^{-7}$ scc/sec He @ 450 psig
Failure Mode	Burst
Natural Frequency	-
Temperature Environment	-
On Orbit Life	-

80420-3 was subjected to the following protoflight tests:

TEST SEQUENCE	TEST DESCRIPTION
1	Examination of Product, Preliminary
2	Volumetric Capacity Measurement
3	Proof Pressure Test
4	Volumetric Capacity Measurement
5	PMD Bubble Point Test
6	Vibration Test
7	Differential Pressure Test
8	Expulsion Efficiency Test
9	PMD Bubble Point Test
10	External Leak Test
11	Weld Quality Inspection
12	Mass Measurement
13	Final Visual Inspection
14	Final Cleanliness & Dry

Vibration Test

Tests conducted on each of the three orthogonal axes.

Test	Propellant Load	Pressurization
(1) Wet sinusoidal vibration test, including pre-test and post-test surveys	251 lbm	MEOP, +10, -0 psig
(2) Wet random vibration test, including pre-test and post-test surveys	251 lbm	MEOP, +10, -0 psig
(3) Dry sinusoidal vibration test, including pre-test and post-test surveys	None	MEOP, +10, -0 psig
(4) Dry random vibration test, including pre-test and post-test surveys	None	MEOP, +10, -0 psig

The MEOP is defined as 414.7 psig @ 122°F.

Temperature (°F)	MEOP Pressure (psig)	Correction Factor (ref.)
40°	443.7	1.070
43°	442.8	1.068
45°	442.2	1.066
48°	441.5	1.065
50°	440.7	1.063
53°	439.8	1.061
55°	438.9	1.058
58°	438.1	1.056
60°	437.2	1.054
63°	436.3	1.052
65°	435.5	1.050
70°	433.7	1.046
73°	432.9	1.044
75°	432.0	1.042
80°	430.3	1.038
83°	429.4	1.035
85°	428.3	1.033
90°	426.4	1.028
95°	424.7	1.024
98°	423.8	1.022
100°	422.9	1.020

Vibration Test (continued)

Specification 087-PF4750, Table 6

Protoflight Sine Vibration Levels

Axis	Frequency (Hz)	Acceleration (g)	Sweep Rate
Wet Tank			
Spacecraft thrust (Z)	5-18	0.5 in DA	4 oct/min
	18-25	12.5	
	25-100	2.5	
Spacecraft lateral (X) and (Y)	5-13	0.5 in DA	4 oct/min
	13-20	12.5	
	20-100	2.0	
Dry Tank			
Spacecraft thrust Z	5-13	0.5 in DA	4 oct/min
	13-50	7.5	
	50-100	2.5	
Spacecraft lateral X and Y	5-13	0.5 in DA	4 oct/min
	13-20	7.5	
	20-100	2.0	

Notes:

1. Sine input may be notched to limit hydrazine tank response to:

   Spacecraft thrust (Z axis): 16.3 g (-0, +5%)
   Spacecraft lateral (X axis): 12.5 g (-0, +5%)
   Spacecraft lateral (Y axis): 6.3 g (-0, +5%)

2. Low level sine sweep survey from 4 to 100 Hz shall be performed prior to and after each vibration axis. Any resonant frequency shift greater than 5% or resonant magnitude change greater than 10% from the pre to post surveys shall require review and approval by Orbital.

3. The 16.3 g thrust, 6.3 g Y lateral and 12.5 g X lateral loads must be reached through resonance even if it means raising the levels of the sine input.

4. Re-test on 1 complete axis is allowed.

Vibration Test (continued)

Protoflight Random Vibration Levels

Frequency (Hz)	Protoflight Level	Units
Wet Tank		
20-50 50-500 500-2000	6 0.16 –3	dB/oct g^2/Hz dB/oct
Overall 13.7 G_{rms} Duration: 60 seconds per axis		
Dry Tank		
20-50 50-500 500-2000	6 0.4 -3	dB/oct g^2/Hz dB/oct
Overall 21.6 G_{rms} Duration: 60 seconds per axis		

Notes:

1. Random input spectra may be notched to limit tank response to:

   Spacecraft thrust (Z axis): 16.3 g (-0, +5%)
   Spacecraft lateral (X axis): 12.5 g (-0, +5%)
   Spacecraft lateral (Y axis): 6.3 g (-0, +5%)

2. Minimum frequency of the test fixture shall be greater than 200 Hz.

3. A low level random survey shall be performed prior to and after each vibration axis. Any resonant frequency shift greater than 5% or resonant magnitude change greater than 10% from pre to post low level surveys shall require review and approval by Orbital.

4. It is permissible to start with a –12dB survey, followed by –9 dB, -6 dB, and –3 dB runs as required prior to starting the full level vibration testing.

Differential Pressure Test

Test measures the pressure differential between ullage and tank outlet. Tank assembly pressure drop shall not exceed 5.0 psid at a maximum flow rate of 0.10 lbm/sec (0.72 gpm).

This differential pressure test measures the actual pressure drop at 0.10 lbm/sec (0.72 gpm) flow rate. Tank is loaded with 251, +0.5/-0 lbm of D. I. water.

1.0 INTRODUCTION

1.1 This report illustrates by verification testing, analysis and/or similarity in lieu of Qualification testing, that the Propellant Tank Assembly (PTA) for the STAR-1 BUS Program, Pressure Systems, Inc. (PSI) Part Number 80420-1, demonstrates conformance to specifications and/or is similar or identical in areas of design, manufacturing processes and quality control to other tanks that have been previously certified to equivalent or more stringent criteria than those specified in the Propellant Tank Performance Specification for STAR-1 BUS, Orbital Sciences Document 087-PF4750, Rev. A.

1.2 Specifically, this plan addresses the Qualification Level of OSC Document 087-PF4750, Rev. A, Section 4.2 and Table 11 Verification Matrix for those Sections indicated as T (Test Method) and including an entry in the Verification list column. Other Sections indicated as required for Qualification (Q) Level are verified by Fracture Mechanics Analysis, Independent evaluations, design, heritage, Acceptance Tests and/or process control. Documentation has previously been provided and/or is available.

1.3 Description & Brief Pedigree: The Propellant Tank Assembly shell design and processing originated with the PSI Part Number 80212 and was modified to eliminate girth lugs for the PSI Part Number 80229, both of which were qualified for Classified programs. The B-SAT-2 tank is virtually identical to PSI Part Number 80281, a derivative of the 80212 and 80229, which was also qualified for a Classified program. The proven shell design and processing was further successfully applied to PSI Part Number 80309.

The 80420-1 tank is a 22-inch x 32-inch long annealed cylindrical pressure vessel constructed of 6AL-4V Titanium. Mounting is accomplished by struts attached to the polar bosses. A vane type propellant management device (PMD) is provided to expel the fuel under low or zero gravity conditions. Connection is made to the propellant and pressurant ports through co-extruded tubes providing a transition from 6AL-4V titanium to 304L corrosion resistant steel.

PSI Part Number 80420-1 belongs to a qualified family of propellant management (PMD) tanks. These tanks have been used successfully on several major space programs. This family of tanks is included in a large product line that offers a variety of internal diameters, unique propellant management criteria, different mounting provisions, tube interfaces and pressure shells. This family is constructed using only 6AL-4V titanium and CRES. These materials have been demonstrated through use to be compatible, with no adverse effects, with all fluids specified. The long term effects and compatibility of hydrazine with 6AL-4V titanium and CRES have been evaluated and documented in reports by several sources.

2.0 REFERENCES

The following documents, of current issue or noted revision, provided analyses, evaluations, quality controls, and test procedures applicable to the Qualification of the Propellant Tank.

2.1 Pressure Systems, Inc.

50-000548, N/C	Acceptance Test Procedure, Part Number 80420-1
50-000547, N/C	Protoflight Test Procedure, Part Number 80420-3
56-000100, N/C	Qualification Test Report, Part Number 80281-1
Job 275, 275A, 275B	Wada Analysis and Report
54-000167, N/C	Fracture Analysis Plan BSAT-2 Hydrazine Tank
24 June 1999	PMD Analysis by Don Jaekle, BSAT-2 Propellant Tank Design Review
50-000546, A	Bubble Point Test Procedures, 80420-1
43254	Wyle Report BSAT-2 Random and Sinusoidal Vibration Tests

2.2 Orbital

087-PF4750, A	STAR-1 BUS Hydrazine Tank Performance Specification

3.0 CONCLUSION

This report provides the references and illustrates by demonstration and/or similarity, in lieu of formal Qualification Testing, that the proposed Propellant Tank for the STAR-1 BUS, PSI Part Number 80420-1, conforms to requirements and/or is similar or identical to other tank designs which have previously been qualified to equivalent or more stringent criteria than those specified in the Performance Specification, ORBITAL Drawing 087-PF4750, Rev. A

4.0 QUALIFICATION MATRIX

087-PF4750, Rev. A SECTION	REQUIREMENT	REFERENCE	DISCUSSION
3.2.1.1	Hydrazine Mass Flow Rate: The tank shall accommodate the mass flow rates delineated for the specified pre-launch and mission environmental conditions	PMD Technology "Orbital" BSAT-2 Propellant Management Device Design Review of June 24, 1999 and PSI Protoflight Test Procedure 50-000547, Paragraphs 4.7 and 4.8	The analysis considers the maximum mass flow rate and concludes that the use of the PMD described will meet all propellant demand phases of the mission. The results of the Protoflight testing verified conformance to this requirement..
3.2.1.2	Maximum Expulsion Pressure Drop: Pressure drop across the tank outlet with the PMD installed shall not exceed 5 psid at a mass flow rate of 0.10 lbm/sec.	PSI Protoflight Test Procedure 50-000547, Paragraph 4.7.	The results of the Protoflight testing verified conformance to this requirement. Maximum measurement of 4.1 psid under stated test conditions.
3.2.1.3	Expulsion Efficiency: The tank and PMD shall expel not less than 99.6% of the hydrazine load under the specified environments.	PMD Technology "Orbital" BSAT-2 Propellant Management Device Design Review of June 24, 1999 and PSI Protoflight Test Procedure 50-000547, Paragraph 4.8	The analysis considers the 99.6% expulsion efficiency and concludes that the use of the PMD described will meet all propellant demand phases of the mission. The Protoflight test was performed for informational purposes only. There is no PMD expulsion efficiency requirement for ground level testing. The calculated efficiency significantly exceeded 99.6%.
3.2.1.4.1	Operating Pressures: The tank shall store and expel hydrazine at the flow rates defined when subjected to the on-orbit pressure cycle (400 – 80 psia). The tank will experience these pressures when loaded with a propellant load equal to or less than 251.0 lbm (25% ullage). These pressure levels shall occur over the 12 year life of the mission.	OSC Specification 087-PF4750, Section 5.3.2.1 defines testing requirements. PSI Protoflight Test Procedure 50-000547, ATP 50-000548, Fracture Analysis Plan 54-000167 and WADA Report 275, A, B.	The OSC Specification defines testing that verifies the conformance of the discrete parameters contained in ensuing Sections of this Matrix. The WADA Fracture Mechanics and Stress Analyses considers the Pressure and External Load History and Vibration Levels. Reference Paragraph 6.0 and Tables 1 through 4 of the Fracture Analysis Plan. Positive margins of safety were found in all cases. The Protoflight and Acceptance Test Procedures contain verification of applicable parameters.

4.0 QUALIFICATION MATRIX (continued)

087-PF4750, Rev. A SECTION	REQUIREMENT	REFERENCE	DISCUSSION
3.2.1.4.2	Tank Proof Pressure: The tank shall withstand exposure to an internal proof pressure of 500 +10/-0 psia at 50 degrees C for 2 minutes without permanent deformation or leakage and shall meet all requirements after proof pressure testing. Section 5.3.2.1.3 further requires a volumetric capacity test following the proof pressure test and verification that there is no lateral growth and less than 0.2% axial growth.	PSI Protoflight Test Procedure 50-000547 Paragraphs 4.3 and 4.4, ATP 50-000548 Paragraphs 4.3 and 4.4, Fracture Analysis Plan 54-000167 and WADA Report 275, A, B.	The WADA Fracture Mechanics and Stress Analyses considers the Proof Pressure. Reference Paragraph 3.3.2 of the Job 275 Stress Analysis. Positive margins of safety were found in all cases. The prototype tank number 80420 was tested at 542 psig at 66 degrees F (in excess of the equivalent of 514.7 at 122 degrees F), with a hold period of 2 minutes and determined to have no post proof lateral or axial growth. The pre and post proof volume was 9226.3 cubic inches. The ATP requires all flight tanks have this testing performed.
3.2.1.4.4	Tank Burst Pressure: The tank shall withstand pressurization to an internal pressure of 600 +10/-0 psia at 50 degrees C without rupture or structural failure.	PSI Qualification Test Report 56-000100 Paragraph 4.5.4 and WADA Report 275, A, B.	The PSI tank number 80281-1, with similar shell burst at 840 psig corrected to 734.6 psig at 120 degrees F. The WADA Fracture Mechanics and Stress Analyses considers the Proof Pressure. Reference Paragraph 3.3.3 of the Job 275 Stress Analysis. Positive margins of safety were found in all cases.
3.2.1.4.8	MEOP Pressure Cycle Life: The tank shall survive 4 times the number of MEOP cycles identified in the Hydrazine Tank Cycle Load History or 50 MEOP cycles, whichever is greater, without permanent deformations or leakage.	WADA Report 275A	The WADA Fracture Mechanics Analysis considers the Pressure Cycling. Reference Paragraph 3.3.1 of the Job 275A Analysis. The conclusion is that the tank meets all of the fracture requirements.
3.2.1.4.9	Proof Pressure Cycle Life: The tank shall survive 12 proof pressure cycles without permanent deformation or leakage.	PSI Fracture Analysis Plan 54-000167 and WADA Report 275A.	The WADA Fracture Mechanics Analysis considers the 12 proof pressure cycles. Reference Paragraph 5.2.3 of the Fracture Analysis Plan. The conclusion is that the tank meets all of the fracture requirements.

4.0 QUALIFICATION MATRIX (continued)

087-PF4750, Rev. A SECTION	REQUIREMENT	REFERENCE	DISCUSSION
3.2.1.5	External Leakage: External leakage from the tank shall not exceed 1.0 x 10^{-6} scc/sec of Ghe when internally pressurized to 400 psia.	PSI Protoflight Test Procedure 50-000547 Paragraphs 4.10 and ATP 50-000548 Paragraph 4.7.	The prototype tank number 80420 was tested at 430 psig at 67 degrees F (within testing tolerance of the equivalent to 400 psia at 122 degrees F). The leakage was found to be orders of magnitude better than the requirement. (6.1 x 10^{-9} std scc/sec) The ATP requires all flight tanks to have this testing performed.
3.2.1.6.1	Minimum PMD Bubble Point: TBS-1.	PSI Protoflight Test Procedure 50-000547 Paragraphs 4.5 and 4.9, ATP 50-000548 Paragraph 4.6 and Test Procedure 50-000546 Paragraph 4.5.	The protoflight tank was subjected to PMD Bubble Testing before and after vibration. Both tests were successful. The Bubble Point Test Procedure defines testing and pass/fail criteria for various levels of PMD assembly. The ATP requires all flight tanks to have post vibration PMD Bubble testing performed.
3.2.2.3	Propellant Load Capacity: The tank shall store and expel a maximum propellant load of 251.0 lbm (25% ullage) measured at standard environmental conditions.	WADA Report 275	The WADA Fracture Mechanics and Stress Analyses considers the hydrazine mass. Reference Paragraph 3.2.2 of the Job 275 Stress Analysis. Positive margins of safety were found in all cases.
3.2.2.4	Volumetric Capacity: The tank internal volumetric capacity shall be at least 9200 cubic inches.	PSI Protoflight Test Procedure 50-000547 Paragraphs 4.2 and 4.4, ATP 50-000548 Paragraphs 4.2 and 4.4.	The volumetric capacity of the protoflight tank was determined before and after proof testing. Both determinations were 9226.3 cubic inches. The ATP requires all flight tanks to have pre and post proof testing volumetric determinations performed.

4.0 QUALIFICATION MATRIX (continued)

087-PF4750, Rev. A SECTION	REQUIREMENT	REFERENCE	DISCUSSION
3.2.2.5	Natural Frequency: The tank shall be modeled using rigid interfaces, pressurized to 400 psia and subjected to the specified environments and shall have a first mode frequency greater than 43 Hz in both the lateral and thrust directions.	PSI Protoflight Test Procedure 50-000547 Paragraph 4.6, ATP 50-000548 Paragraph 4.5, Wyle Report 43254 and WADA Report 275.	The WADA Analysis determined a first tank frequency of 207 HZ. Reference 4.2. The prototype tank was subjected to sine and random vibration testing which included a low level sweep survey prior to and after each vibration axis. The Wyle Report indicates tha any response anomalies during the survey significantly exceeded 43 Hz. The ATP requires all flight tanks to have a low level random survey prior to and after each random vibration axis.
3.2.6	Environmental Conditions: The tank shall be designed to meet all performance requirements during and after exposure to the specified pre-launch, launch and mission environmental conditions.	PSI Fracture Analysis Plan 54-000167, WADA Report 275, A, B.	The WADA Analysis considers the environmental conditions, as required in the Fracture Analysis Plan, and concludes that the design meets or exceeds the requirements. This PMD tank family, including similar designs has successfully performed in a broad spectrum of environments.
3.2.6.4.1	Sine Vibration: The tank wet or dry, when supported as specified, shall not suffer any performance degradation when subjected to protoflight and acceptance sine vibration levels.	PSI Fracture Analysis Plan 54-000167, Protoflight Test Procedure 50-000547, Paragraph 4.6 Step 10, WADA Report 275, A, B, and Wyle Report 43254.	The WADA Analysis considers the specified environmental conditions and concludes that the design meets the requirements. The Protoflight tank was subjected to sine vibration testing to the requirements authorized by PSI and OSC test engineers. The envelope exceeded the requirements of Table 5 of the Specification. During and after vibration tests, the tank was inspected for damage. Successful completion of post – vibration PMD bubble point test and leak test validated the vibration testing.

4.0 QUALIFICATION MATRIX (continued)

087-PF4750, Rev. A SECTION	REQUIREMENT	REFERENCE	DISCUSSION
3.2.6.4.2	Random Vibration-Wet: The tank, when supported as specified, shall not suffer any performance degradation when subjected to protoflight and acceptance random vibration levels.	PSI Fracture Analysis Plan 54-000167, Protoflight Test Procedure 50-000547, Paragraph 4.6 Step 10, ATP 50-000548 Paragraph 4.5 Sept 10, WADA Report 275, A, B, and Wyle Report 43254.	The WADA Analysis considers the specified environmental conditions and concludes that the design meets the requirements. The Protoflight tank was subjected to random vibration testing to the requirements authorized by PSI and OSC test engineers. The envelope exceeded the requirements of Table 7 of the Specification. During and after vibration tests, the tank was inspected for damage. Successful completion of post – vibration PMD bubble point test and leak test validated the vibration testing. The ATP requires all flight tanks to have a wet random vibration test, followed by successful completion of post – vibration PMD bubble point test and leak test.

5.0 ATTACHMENTS

50-000548, N/C 80420-1	Acceptance Test Procedure, Part Number
50-000547, N/C 3	Protoflight Test Procedure, Part Number 80420-
56-000100, N/C	Qualification Test Report, Part Number 80281-1
Job 275, 275A, 275B	Wada Analysis and Report
54-000167, N/C	Fracture Analysis Plan BSAT-2 Hydrazine Tank
24 June 1999	PMD Analysis by Don Jaekle, BSAT-2
Propellant Tank Design Review	
43254	Wyle Report BSAT-2 Random and Sinusoidal Vibration Tests