DRAFT

Magnetospheric Multiscale (MMS) Project

Propulsion Subsystem

Propellant Tank Specification

Effective Date: TBD

National Aeronautics and
Space Administration

Goddard Space Flight Center
Greenbelt, Maryland

CM FOREWARD

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CHANGE HISTORY LOG

Revision Level	DESCRIPTION OF CHANGE	CCR / SCoRe No.	DATE APPROVED
-	Initial Release	CCR-0145	TBD

List of TBDs/TBRs

Item No.	Location	Summary	Ind./Org.	Due Date
1				

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1.0 INTRODUCTION

1.1 GENERAL INFORMATION

The Magnetospheric Multiscale (MMS) mission is the fourth mission of the Solar Terrestrial Probe (STP) program of the National Aeronautics and Space Administration (NASA). The MMS mission will use four identically instrumented observatories to perform the first definitive study of magnetic reconnection in space and will test critical hypotheses about reconnection. Magnetic reconnection is the primary process by which energy is transferred from the solar wind to the Earth's magnetosphere and is also fundamental to the explosive release of energy during substorms and solar flares.

The MMS mission will study magnetic reconnection in the Earth's magnetosphere. The four MMS observatories will be required to fly in a tetrahedral formation in order to unambiguously determine the orientation of the magnetic reconnection layer.

1.2 SCOPE

This specification describes the electrical, mechanical, environmental, and verification testing requirements for a space-qualified Propulsion Subsystem *Propellant Tank* for a Goddard Space Flight Center (GSFC) payload, the Magnetospheric Multiscale (MMS) Mission.

2.0 APPLICABLE DOCUMENTS

The following documents and drawings in effect on the day this specification was signed **shall** apply to the fabrication and to the electrical, mechanical, and environmental requirements of the *propellant tank* to the extent specified herein. In the event of conflict between this specification and any referenced document, this specification will govern, with the exception of the Magnetospheric Multiscale *Propellant Tank* Statement of Work (461-*PS*-SOW-0*013*), in which case the Statement of Work (SOW) takes precedence.

The following is a list of the applicable specifications and publications.

Table 2-1 Applicable Documents

Section	Document Number	Title	Revision/Date
Many	461-*PS*-SOW-0*013*	MMS *Propellant Tank* Statement of Work	*TBD*
Many	461-*PS*-LIST-0*026*	MMS *Propellant Tank* DILS	*TBD*
Many	AFSPCMAN 91-710	Range Safety User Requirements	07/01/2004
6.1	NASA-STD-5001A	Structural Design And Test Factors Of Safety For Spaceflight Hardware	08/05/2008
6.4.2	NASA-HDBK-7005	Dynamic Environment Criteria	BASE/ 3/13/2001
6.4.2	NASA-STD-7001	Payload Vibroacoustic Test Criteria	BASE/ 6/21/1996
7.1.1.2	IEST-STD-CC1246D	Product Cleanliness Levels And Contamination Control Program	2002
8.1.2.1	AMS 2488	Anodic Treatment - Titanium and Titanium Alloys Solution Ph 13 Or Higher	06/01/2000
8.1.2.2	MIL-PRF-26536E	Performance Specification Propellant, Hydrazine	Rev. E/ Sept. 1997
8.1.2.2	JSC-SPEC-C-20C	Water, High Purity, Specification for	06/14/1976
8.1.2.2	MIL-PRF-27401D	Propellant, Nitrogen, Pressurizing Agent	10/03/1995
8.1.2.2	MIL-PRF-27407B	Propellant, Helium, Pressurizing Agent	08/25/1997
8.1.2.2	MIL-PRF-27415A	Propellant Pressurizing Agent, Argon	12/11/1997

3.0 CONTRACT DESCRIPTION

3.1 *PROPELLANT TANK* DESCRIPTION

The MMS Propulsion Subsystem *Propellant Tank* will have separate pressurant and propellant compartments. It will store *102.5 kg of propellant* and feed continuous gas-free propellant to thrusters.

Each of the four (4) spacecraft to be built will require four (4) propellant tanks. Please refer to the Statement of Work (SOW, 461-PS-SOW-0013) and the Deliverable Items List and Schedule (DILS, 461-PS-LIST-0026) for a complete list of all hardware, verification testing, test reports, design reports, and analyses reports that should be delivered with or before the propellant tanks.

3.2 GROUND SUPPORT EQUIPMENT DESCRIPTION

N/A

4.0 FUNCTIONAL/PERFORMANCE REQUIREMENTS

The component **shall** be designed to withstand the operational and non-operational environments specified in the following section without degradation to mission goals and performance requirements.

4.1 *PROPELLANT TANK* FLIGHT UNIT FUNCTIONAL/PERFORMANCE REQUIREMENTS

4.1.1 Pressure

4.1.1.1 MEOP

The Maximum Expected Operating Pressure (MEOP) **shall** be 325 psia at 50 °C.

Rationale: Derived from the MMS Propulsion Subsystem Spec, 461-PS-SPEC-0035

4.1.1.2 Proof Pressure

Proof pressure capability of the propellant tank **shall** be at least 406 psia.

Rationale: MEOP x 1.25; refer to AFSPCMAN 91-710

4.1.1.3 Burst Pressure

Burst pressure of the propellant tank **shall** be at least 488 psia.

Rationale: MEOP x 1.5; refer to AFSPCMAN 91-710

4.1.1.4 Collapse Pressure

The tank **shall** withstand a complete internal vacuum.

4.1.1.5 Differential Pressure

4.1.1.5.1 Differential Pressure Capability

The *propellant tank* **shall** be capable of at least 150 psi differential between the pressurant and propellant ports at EOL.

Rationale: MMS Preliminary Blowdown Analysis, 461-PS-ANYS-0022

4.1.1.5.2 Differential Pressure during Normal Expulsion

The *propellant tank* **shall** have less than 15 psi differential between the pressurant and propellant ports while expelling at a hydrazine flow rate of 1.65 lb/sec (0.75 kg/sec).

4.1.1.6 Interface Tube Design Pressure

4.1.1.6.1 Proof Pressure

The interface tube design proof pressure capability of the propellant tank **shall** be at least 788 psia.

Rationale: (MEOP + 200 (Back-relief Pressure)) x 1.5 for lines and fittings with diameter less than 1.5 in; refer to AFSPCMAN 91-710

4.1.1.6.2 Burst Pressure

The interface burst pressure of the propellant tank **shall** be at least 2100 psia.

Rationale: (MEOP + 200 (Back-relief pressure)) x 4 for lines and fittings with diameter less than 1.5 in; refer to AFSPCMAN 91-710

4.1.2 Leakage

4.1.2.1 External Leakage

The external leakage rate of the propellant tank **shall** not exceed 10^{-6} sccs He.

Rationale: Required level maintains system performance throughout the mission per Leakage Analysis, 461-PS-ANYS-0027

4.1.2.2 Internal Leakage

Internal leakage across from the pressurization side to the propellant side **shall** not exceed 265 sccs per 15 minutes when the pressurization side is pressurized to 120 +/- 10 psig with gaseous helium.

Rationale: Based on acceptance level test of a similar tank

4.1.3 Expulsion Efficiency

The expulsion efficiency **shall** be greater than 99.9% the usable volume of the propellant mass in 5.2.2.

4.1.4 Leak Before Burst

The tanks **shall** be designed to leak before burst per AFSPCMAN 91-710.

Rationale: the MMS Propulsion Subsystem mass allocation for PDR on MIS

4.2 RESOURCE ALLOCATIONS

4.2.1 Mass Allocation

The *propellant tank* including all hardware required to mount to the strut supports **shall** have a total mass less than or equal to *12.1* kg.

Rationale: TBD

4.2.2 Nominal Power Allocation

N/A

4.2.3 Peak Power Allocation

N/A

4.2.4 Deployment Power Allocation

N/A

4.2.5 Telemetry

N/A

4.3 POWER

N/A

4.4 ELECTRICAL GROUNDING

N/A

4.5 SIGNAL AND DATA INTERFACES

N/A

4.6 OPERATING MODES

N/A

4.7 COMMAND AND DATA SERVICES

N/A

4.8 FLIGHT SOFTWARE

N/A

4.9 NEA/EED DESIGN

N/A

5.0 PHYSICAL REQUIREMENTS

Of four (4) *propellant tanks* per S.C., two (2) will be installed upright and the other two (2) will be installed upside-down. The following physical requirements apply to both configurations.

5.1 INTERFACE DOCUMENTATION

See Section 3.1 of the MMS Propellant Tank Statement of Work, 461-PS-SOW-0013.

5.2 MASS PROPERTIES

5.2.1 Component Masses

See Section 4.2.1.

5.2.2 Propellant Mass

The *propellant tank* **shall** be able to contain minimum 102.5 kg of Hydrazine at BOL.

Rationale: (Total Required Amount of Propellant per S.C. for the Mission)/4

5.2.3 Oscillating Slosh Mass

The oscillating slosh mass (non-slosh mass + effective slosh mass) **shall** be less than the values in Table 5-1.

Table 5-1 Oscillating Slosh Mass

Fill Fraction	Oscillating Slosh Mass (Non-Slosh Mass + Effective Slosh Mass) kg (=N/g)		
	$\omega \ll \omega_n$	$\omega = \omega_n$	$\omega \gg \omega_n$
80%	113	176	98
65%	92	172	74
50%	71	124	59
20%	29	84	16.7

Rationale: Based on ground-based lateral tests of a similar tank that bounds the slosh

5.2.4 Center of Mass Location

See Section 3.1 of the MMS Propellant Tank Statement of Work, 461-PS-SOW-0013.

5.2.5 Center of Mass Accuracy

The center of mass, including all the metal components of the tank, **shall** be determined to within *±1.0 mm* relative to an external reference.

Rationale: MMS Propulsion Subsystem Specification, 461-PS-SPEC-0035

5.2.6 Moments of Inertia

The contractor **shall** calculate the moment of inertia.

5.2.7 Products of Inertia

The contractor **shall** calculate the products of inertia.

5.2.8 Determination of Moments and Products of Inertia

N/A

5.3 VOLUME

The *propellant tank* **shall** have an internal volume of at least 10,700 in^3 for gas and propellant.

Rationale: the MMS Propulsion Subsystem for PDR on MIS

5.4 PHYSICAL ENVELOPE

The *propellant tank* **shall** not exceed the thermal and mechanical volume envelope per Figure 5-1 and Figure 5-2. All dimensional units are in inches in the following figures.

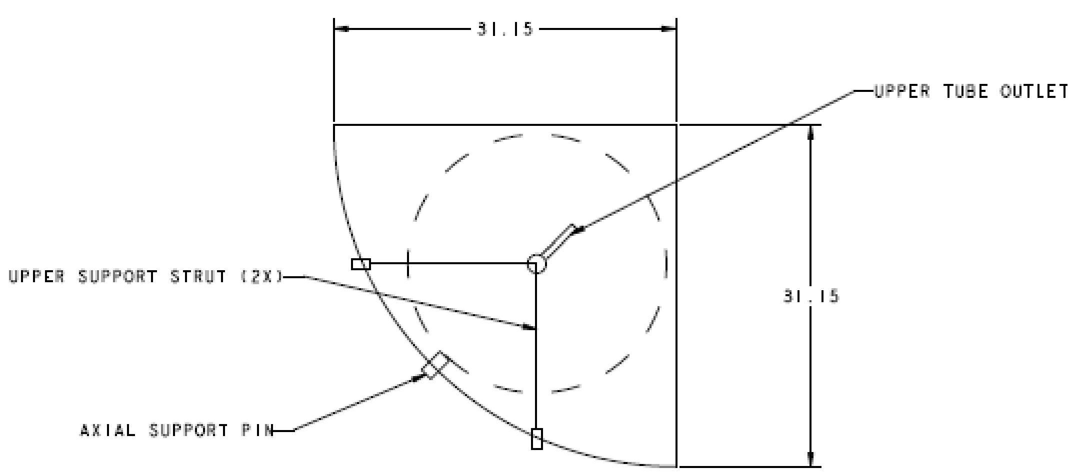

Figure 5-1 Tank Top View

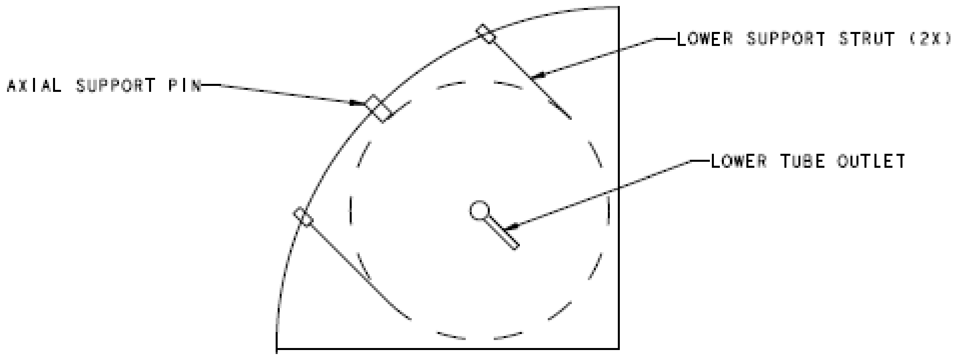

Figure 5-2 Tank Bottom View

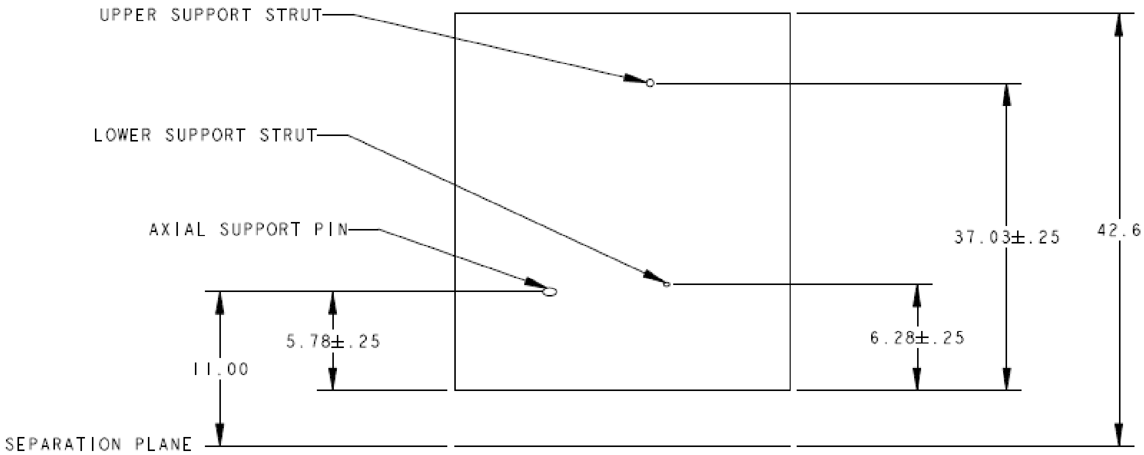

Figure 5-3 Tab Location

5.5 FLUID INTERFACES

Fluid interfaces **shall** be 0.25”±0.003 inch outer diameter with a 0.028”±0.003 wall thickness, and the material **shall** be SS-304L.

5.5.1 Interface Tube Locations

Interface tubes (tube outlets) **shall** be located and clocked per Figure 5-1 and Figure 5.2.

Rationale: the MMS Propulsion Subsystem for PDR on MIS

5.6 MOUNTING

The *propellant tank* will be mounted onto the MMS S.C. using struts and axial support pins. Struts will prevent lateral motion, and axial support pins will prevent axial motion. The following mounting configurations apply to both propellants up and down configurations.

5.6.1 Struts

Mounting struts **shall** be located and oriented per Figure 5-1 and Figure 5-2. Rod ends will be utilized for the connection between the MMS S.C. and struts.

Rationale: the MMS Propulsion Subsystem for PDR on MIS

5.6.2 Axial Support Pin

The axial support pin **shall** be located as shown in Figure 5-1, Figure 5-2 and Figure 5-3.

Rationale: the MMS Propulsion Subsystem for PDR on MIS

5.7 ALIGNMENT

N/A

6.0 ENVIRONMENTAL REQUIREMENTS

Environmental design requirements for the spacecraft components are specified in this section. The MMS spacecraft components will be capable of meeting their performance requirements after exposure to the environments specified in this section.

All loads and environments in this document are preliminary and will be updated as the MMS spacecraft is defined.

6.1 MECHANICAL FACTORS OF SAFETY

The *propellant tank* as well as Mechanical Ground Support Equipment (MGSE) **shall** demonstrate positive Margins of Safety under limit loads for all yield and ultimate failures using the Factors of Safety (FS) defined in Table 6-1 (see NASA-STD-5001A for more information on other materials [e.g. glass]). Margin of Safety (MS) is defined as follows:

MS = (Allowable Stress(or Load)/(Applied Limit Stress(or Load) x FS)) -1

Table 6-1 Factors of Safety

Type of Hardware[1,]	Static/Sine	Random/Acoustic[2]
Tested Metallic Structure Yield	1.25	1.6
Tested Metallic Structure Ultimate	1.4	1.8
Stability Ultimate	1.4	1.8
Bonded Inserts/Joints Ultimate	1.5	1.9
Untested Flight Structure Yield- metallic only	2.0	
Untested Flight Structure Ultimate - metallic only	2.6	
Ground Support Equipment Yield	3.0	
Ground Support Equipment Ultimate	5.0	
Transportation Dolly/Shipping Container Yield	2.0	
Transportation Dolly/Shipping Container Ultimate	3.0	

1 – Factors of safety for pressurized systems to be compliant with AFSPCMAN 91-710, “Range Safety User Requirements.”
2 – Factors shown should be applied to statistically derived peak response based on RMS level. As a minimum, the peak response **shall** be calculated as a 3-sigma value.

6.2 QUASI-STATIC ACCELERATION

Quasi-static acceleration represents the combination of steady-state accelerations and the low frequency mechanically transmitted dynamic accelerations that occur during launch.

The *propellant tank* **shall** demonstrate its ability to meet its performance requirements after being subjected to the net CG limit loads shown in Table 6-2.

Linear interpolation should be used between breakpoints to determine the appropriate limit load as a function of *propellant tank* weight. Note that these design limit loads are intended to cover only the low frequency launch environment and must be used in conjunction with the random vibration environments to assess structural margins.

Table 6-2 Propellant Tank Limit Loads

Propellant Tank **Mass (kg)**	**Limit Load (g, any direction)**
0.5 or less	35.9
1	35.0
5	30.1
10	26.5
20	22.4
40	18.2
60	15.9
80	14.3
100	13.2
125	12.1
150	11.2
175	10.6
200	10.0
225	9.5

Rationale: MMS Environmental Requirements Document, 461-SYS-RQMT-0023

6.3 FREQUENCY REQUIREMENT

6.3.1 Fundamental Launch Frequencies

The *propellant tank* **shall** have a fundamental frequency greater than *50* Hz when hard mounted at its SC interface. If the propellant tank is less than 50 Hz, then the frequencies and mode shapes must be test-correlated.

Rationale: MMS Environmental Requirements Document, 461-SYS-RQMT-0023

6.3.2 On-Orbit Frequencies

N/A

6.4 VIBRATION

6.4.1 Sinusoidal Vibration

The *propellant tank* **shall** demonstrate its ability to meet its performance requirements after being subjected to the sine vibration environment in Table 6-3, applied at the MMS to *propellant tank* interface (both wet tanks and dry tanks will see the sine vibrations environment at different times). This environment will be updated when coupled loads analysis results are available. See the MMS Propulsion *Propellant Tank* SOW for definitions of Protoflight, Qual, and Acceptance.

Table 6-3 *Propellant Tank* Sine Vibration Environment

Test	Axis	Frequency (Hz)	Level (Peak)	Sweep Rate (Octaves/Min)
Acceptance	Thrust	5 – 50	10.0 g	4
	Lateral	5 – 50	10.0 g	4
Proto-flight	Thrust	5 – 50	12.5 g	4
	Lateral	5 – 50	12.5 g	4
Qualification	Thrust	5 – 50	12.5 g	2
	Lateral	5 – 50	12.5 g	2

Levels may be notched to not exceed 1.25 times the design limit load. These levels will be updated as coupled-loads analysis (CLA) data becomes available. *Propellant tank* **shall** test for this environment up to 50 Hz and be analyzed from 50 to 100 Hz. Peak levels at the low end of the frequency range (5 – 20 Hz typically) may be ramped up as needed to accommodate shaker table displacement limitations.

Rationale: MMS Environmental Requirements Document, 461-SYS-RQMT-0023

6.4.2 Random Vibration

The *propellant tank* **shall** demonstrate its ability to meet its performance requirements after being subjected to the random vibration environment in Table 6-4, applied at the MMS to *propellant tank* interface.

Table 6-4 *Propellant Tank* Random Vibration Environment

Frequency (Hz)	Protoflight/Qual Level	Acceptance Level
20	0.01 g^2/Hz	0.013 g^2/Hz
20 – 50	(10*log((0.16*22.7/W)/.01))/1.32 dB/Octave	10*log((0.08*22.7/W)/.01))/1.32 dB/Octave
50 – 800	0.16*(22.7/W) g2/Hz	0.08*(22.7/W) g^2/Hz

800 – 2000	(10*log(.01/(0.16*22.7/W)))/1.32 dB/Octave	-(10*log(.01/(0.08*22.7/W)))/1.32 dB/Octave
2000	0.01 g^2/Hz	0.01 g^2/Hz
Overall (G_{rms})	calculate grms	calculate grms
Duration (minutes)	1 (protoflight), 2 (Qual)	1

W = weight of the tank system in kg.

The above random environment is appropriate for wet *propellant tanks* weighing more than 59 kg (130 lbs) or less. This environment may be updated with random vibration analysis. Note for lightweight *propellant tank*, the highest design loads may be from this random vibration environment. The contractor **shall** perform random vibration analysis along with static loads analysis. Please see NASA-HDBK-7005 and NASA-STD-7001 for more information.

Rationale: MMS Environmental Requirements Document, 461-SYS-RQMT-0023

6.5 SHOCK

The *wet propellant tank* **shall** be designed to meet its performance requirements after being subjected to the shock environment in Table 6-5, applied at the *propellant tank* interface.

Table 6-5 Limit Level Shock Response Spectrum

Frequency (Hz)	Acceptance Level	Proto-flight Level
100 100 to 468 468 to 3000	*107*g + *7.3* dB/Octave *985* g	*150* g + *7.3* dB/Octave *1389* g
3000 to 10000 10000	+ *7.8* dB/Octave *1313*g	+ *7.8* dB/Octave *1852*g
Three Mutually Perpendicular Axes		

Rationale: MMS Environmental Requirements Document, 461-SYS-RQMT-0023

6.6 ACOUSTICS

The *propellant tank* **shall** be designed to meet its performance requirements after being subjected to the acoustic environment listed in Table 6-6.

Table 6-6 Limit Level Acoustic Environments

Center Frequency (Hz)	Max Predicted Sound Pressure Level (dB)
25	114.0
31.5	120.3
40	127.5

50	122.5
63	124.0
80	124.5
100	126.0
125	126.0
160	127.1
200	127.0
250	126.5
315	126.0
400	126.0
500	124.5
630	122.0
800	119.5
1000	116.5
1250	114.0
1600	112.0
2000	114.0
2500	111.0
3150	110.0
4000	109.0
5000	108.5
6300	108.0
8000	109.7
10000	110.5
OASPL	137.1
Duration	1 minute flight and 2 minutes non-flight hardware

The reference point is 20 μPa.

Rationale: MMS Environmental Requirements Document, 461-SYS-RQMT-0023

6.7 TRANSPORTATION

N/A

6.8 PRESSURE

6.8.1 Operating Pressure Range

The *propellant tank* **shall** be designed to meet all performance requirements while operating over a pressure range of 1.08 x 10^5 N/m^2 (813 Torr) to 1.3 x 10^{-12} N/m^2 (1 x 10^{-14} Torr).

Rationale: MMS Environmental Requirements Document, 461-SYS-RQMT-0023

6.8.2 Maximum Depressurization Rate

N/A

6.9 ON-ORBIT DYNAMIC ENVIRONMENT

Linear and angular accelerations due to the spinning observatory as well as thruster firings are given in the following paragraphs. The *Propellant tank* **shall** be designed to handle all combinations of linear and angular acceleration requirements at the same time, i.e. the linear and angular acceleration are not mutually exclusive.

Rationale: MMS Environmental Requirements Document, 461-SYS-RQMT-0023

6.9.1 Maximum Spin Rate Radial Acceleration

The propellant tank (except the accelerometer and star sensors) **shall** be designed to meet all performance requirements while experiencing the maximum radial acceleration, due to a spin rate of 7.5 rpm, at each component's radial distance from the spin axis.

Rationale: MMS Environmental Requirements Document, 461-SYS-RQMT-0023

6.9.2 Operational Spin Rate Radial Acceleration Range

The propellant tank **shall** be designed to meet all performance requirements while experiencing operational radial accelerations due to spin rates of 2.8-3.2 rpm, at each component's radial distance from the spin axis.

Rationale: MMS Environmental Requirements Document, 461-SYS-RQMT-0023

6.9.3 Dynamic Radial Linear Acceleration

The propellant tank **shall** be designed to meet all performance requirements while experiencing linear accelerations of 0.089 m/s^2 in the radial direction twice per spin cycle and 180 degrees apart, with a maximum burn angle of 64 degrees each, lasting for a total maneuver time of up to 45 minutes.

Rationale: MMS Environmental Requirements Document, 461-SYS-RQMT-0023

6.9.4 Dynamic Axial Linear Acceleration

The propellant tank **shall** be designed to meet all performance requirements while experiencing linear accelerations of 0.012 m/s^2 in the spin axis direction, lasting for 45 minutes of continuous firing.

Rationale: MMS Environmental Requirements Document, 461-SYS-RQMT-0023

6.9.5 Dynamic Transverse Angular Acceleration

The propellant tank **shall** be designed to meet all performance requirements while experiencing angular accelerations of 0.024 rad/s^2 in the spin (transverse) plane once per spin cycle, with a maximum duration of 0.5 seconds, lasting for a total maneuver time of up to 3.6 minutes.

Rationale: MMS Environmental Requirements Document, 461-SYS-RQMT-0023

6.9.6 Dynamic Axial Angular Acceleration

The propellant tank **shall** be designed to meet all performance requirements while experiencing angular accelerations of 0.02 rad/s^2 about the spin axis once per spin cycle, with a maximum duration of 0.8 seconds, lasting for a total maneuver time of up to 6 minutes.

Rationale: MMS Environmental Requirements Document, 461-SYS-RQMT-0023

6.10 HUMIDITY

The *propellant tank* **shall** be able to meet performance requirements after exposure to relative humidity levels of 35% to 70%.

Rationale: MMS Environmental Requirements Document, 461-SYS-RQMT-0023

6.11 THERMAL REQUIREMENTS

6.11.1 Flight Interface Design Temperature Limits

The *propellant tank* **shall** be capable of surviving indefinitely when its temperatures are within the limits shown in Table 6-7 without damage or permanent performance degradation.

Table 6-7 Temperature Levels at Mounting Interface

	Minimum Temperature (ºC)	Maximum Temperature (ºC)
Operational (In Spec)	+12	+40
Protoflight/Acceptance (In Spec)	+12	+50
Survival (Unpowered)	+10	+50
Survival (No Propellant)	+10	+60

Rationale: MMS Environmental Requirements Document, 461-SYS-RQMT-0023

6.11.2 Ground Test Environment

The tank **shall** be capable of supporting 102.5 kg applied evenly over the top dome of the tank.

6.11.3 Allocation of Spacecraft Monitored Temperature Sensors

N/A

6.12 CHARGE PARTICLE RADIATION REQUIREMENTS

N/A

7.0 CLEANLINESS

At delivery, the *propellant tank* should be sufficiently clean so as not to adversely affect its own performance, as well as not be a source of contamination to other items. In addition, the *propellant tank* should not generate contaminants following delivery in excess of that permitted below by virtue of its design, materials of construction, or operation.

7.1 SURFACE CONTAMINATION

7.1.1 Surface Contamination Levels at Delivery

7.1.1.1 Particulate Contamination

N/A

7.1.1.2 Molecular Contamination

N/A

7.1.1.3 External Cleanliness

All hardware surfaces **shall** be verified to be “visibly clean, highly sensitive” per JSC-SN-C-0005C, prior to deliver to NASA/GSFC. This is accomplished by maintaining all hardware in a double bag for storage.

7.1.1.4 Internal Cleanliness

The propulsion components, lines, and fittings **shall** be cleaned, and verified internally clean, to level 100A per IEST-STD-CC1246 (as modified by the following: no metal particles allowed above 25 um) prior to integration in the system.

7.1.2 Surface Contamination Generation

N/A

7.2 ELECTROSTATIC CLEANLINESS

N/A

7.3 MAGNETIC CLEANLINESS

7.3.1 Minimizing Permanent Fields

The *propellant tank* **shall** not contain any of the materials described in Table 7-1. Exceptions to this requirement can be made case by case upon completion of the magnetic assessment and the MMS project office approval.

Table 7-1: Prohibited Magnetic Materials List

Alloy 426	Mumetal
Alloy 720[1]	Nichrome
Carbon Steel 1008	Nickel 200, 270
Chromium	Nickel Iron
Cobalt	Pelcoloy
Copperweld	Permalloy
Dumet	Platinum
Electroless Nickel (except high-phosphorous)	Remendur
Electroloy	Rodar
Elinvar	Stainless Steel 202[2]
Fenicoloy	Stainless Steel 302[2]
Ferrites	Stainless Steel 303[2]
Gridaloy M, P	Stainless Steel 304[2]
Haynes Alloy #6	Stainless Steel 403 & 405
Invar	Stainless Steel 410 & 416
Iron	Stainless Steel 430 & 446
Kovar	Stainless Steel AISI 440C
Mesoloy	Supermalloy
Molypermalllow	Ti 430
Monel K[1]	Vicalloy
Monel R	

[1]Based on a GSFC Materials Engineering Branch Technical Information Paper No. 128 entitled, "Minimizing Stray Magnetic Fields through Materials Selection".

[2]Non-magnetic (technically paramagnetic) in the annealed condition. If any of these alloys are cold worked then they will become magnetic. The alloy condition will be clearly indicated on the Material Certification that will accompany the purchase.

[3]Inconel alloys, 600, 625 and 718, are considered non-magnetic, but become magnetic at cryogenic temperatures.

8.0 DESIGN & CONSTRUCTION REQUIREMENTS

8.1 PARTS, MATERIALS & PROCESSES (PMP)

8.1.1 EEE Parts

N/A

8.1.2 Materials

The *propellant tank* contractor's Quality Assurance system for materials **shall** be in accordance with the requirements in the SOW.

8.1.2.1 Metallic Requirement

Titanium surfaces **shall** be finished per AMS 2488.

8.1.2.2 Fluid Compatibility

All materials **shall** be compatible with prolonged exposure to the following fluids:

- De-ionized water per JSC-SPEC-C-20
- Hydrazine per MIL-PRF-26536E, High Purity
- GHe per MIL-PRF-27407B
- Grade A, Ar per MIL-PRF-27415A Amendment 1
- Grade A, GN2 per MIL-PRF-27401D

8.1.3 Software Assurance

N/A

8.2 ELECTRICAL

N/A

8.3 SAFETY

N/A

8.4 ELECTROMAGNETIC COMPATIBILITY

N/A

8.5 IDENTIFICATION AND MARKING

Each unit **shall** be permanently marked with the part number and a unique sequential serial number in the area designated on the interface control drawing in a manner to be approved by the GSFC COTR.

All markings **shall** use alcohol proof ink.

Rationale: MMS Propulsion Subsystem Specification, 461-PS-SPEC-0035

8.6 WORKMANSHIP

8.6.1 Workmanship Standards

The workmanship standards and processes outlined in the SOW **shall** be used.

8.6.2 Connector

N/A

8.6.3 Safe/Arm Plugs

N/A

8.7 INTERCHANGEABILITY

The propellant tank **shall** be directly interchangeable in form, fit, and function with other items of the same part number.

Rationale: MMS Propulsion Subsystem Specification, 461-PS-SPEC-0035

8.8 RELIABILITY

8.8.1 Mission Life

The *propellant tank* **shall** meet all performance specifications throughout 1 year of ground testing and 28 months of operation in space.

Rationale: MMS Propulsion Subsystem Specification, 461-PS-SPEC-0035

8.8.2 Shelf Life

The *propellant tank* **shall** not suffer any degradation in performance when stored for five (5) years either on the S/C or in bonded storage.

Rationale: MMS Propulsion Subsystem Specification, 461-PS-SPEC-0035

8.9 GROUND HANDLING

8.9.1 Storage Boxes

Storage boxes **shall** be stackable and include studs to allow easy forklift use.

9.0 LOGISTICS

N/A

10.0 VERIFICATION REQUIREMENTS

This Section has been moved to Section 5.0 of the Magnetospheric Multiscale System Propellant Tank Statement of Work (461-PS-SOW-0013).

APPENDIX A ABBREVIATIONS AND ACRONYMS

Abbreviation/ Acronym	Definition
Al	Aluminum
BOL	Beginning of Life
CCB	Configuration Control Board
CCR	Configuration Change Request
CG	Center of Gravity
CLA	Coupled-loads Analysis
CM	Configuration Management
CMO	Configuration Management Office
CMOS	Complementary Metal Oxide Semiconductor
COTR	Contracting Officer's Technical Representative
DILS	Deliverable Items List and Schedule
EOL	End of Life
FS	Factor of Safety
GSE	Ground Support Equipment
GSFC	Goddard Space Flight Center
ICD	Interface Control Drawing
I&T	Integration and Test
MGSE	Mechanical Ground Support Equipment
MMS	Magnetospheric Multiscale
MEOP	Maximum Operating Pressure
MS	Margin of Safety
NASA	National Aeronautics and Space Administration
ω	Slosh Frequency
PDL	Product Design Lead
RMS	Root Mean Squared
SC	Spacecraft
SCoRe	Signature Controlled Request
SOW	Statement of Work
STP	Solar Terrestrial Probe
TBD	To Be Defined
TBR	To Be Reviewed