Statement of Work

for

Global Precipitation Measurement (GPM) Project

Core Spacecraft Propellant Tank

422-06-01-11-003

9/20/07

National Aeronautics and Space Administration

Goddard Space Flight Center
Greenbelt, Maryland

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1.0 Introduction

1.1 General Information

This document defines the work to be performed for Contractor design, development, fabrication, and delivery of the GPM Demisable Propellant Tanks, from here on referred to as the propellant tank(s) or tank(s).

This SOW is for a tank configuration consisting of carbon fiber composite overwrapping an aluminum liner with an aluminum surface tension propellant management device. Positive expulsion device (diaphragm and bladder) are not covered by this SOW.

NASA Policy Directive 8710.3 and NASA Safety Standard 1740.14 provide guidelines for the safe disposal of spacecraft that have completed their missions. In order to achieve safe disposal GPM has chosen to design its spacecraft to demise upon entering the atmosphere. For GPM, titanium and steel tanks of any thickness (including overwrapped) have been found by analysis to survive reentry and cause a significant amount of debris. The GPM tank will consist of an aluminum membrane overwrapped with composite. This configuration has been shown by analysis to demise upon entering the atmosphere. No further demise analyses are required of the tank Contractor.

1.2 General Requirements

The Contractor shall provide the personnel, facilities, and materials necessary to design, fabricate, assemble, test, and deliver one each of the following:

- Development tank
- Qualification tank (after completion of burst test)
- Flight tank

The Contractor shall generate a matrix listing each section in this statement of work reflecting either compliance or non-compliance. Areas of non-compliance need to be addressed by the Contractor showing how they plan to meet the requirement(s) or why it will remain non-compliant.

1.3 Applicable Documents

All applicable and reference documentation identified in this document shall apply in the situations where they are specifically referenced. In the event of a conflict between the SOW and the specification, the SOW shall take precedence. See Appendix C for a list of referenced documents.

2.0 Management, Reporting, Reviews and Documentation

2.1 Management and Reporting

2.1.1 Single Point of Contact

The Contractor shall designate a single individual who will be given full responsibility and authority to manage and administer all phases of the work specified by the contract and ensure that all objectives are accomplished within schedule and cost constraints.

The Contractor shall designate and identify by name a single individual who shall serve as a point of contact with the GSFC Contracting Officer's Technical Representative (COTR) for all technical aspects of the propellant tanks contract.

The Contractor shall perform all necessary functions to manage program resources, control schedules, and manage engineering, manufacturing and procurement activities. The Contractor shall perform all necessary configuration management, Quality Assurance, documentation control, and distribution functions.

2.1.2 Status Reporting

2.1.2.1 Weekly Status Meeting

The Contractor shall plan for weekly status meetings. This meeting will generally be held via teleconference and will be informal. The Contractor and the COTR shall agree upon the scheduling and format of the meeting after contract award. The meeting will not be held on weeks that have higher level meetings scheduled or by mutual agreement between the Contractor and the COTR. The Contractor shall include highlights from the meetings in the monthly report.

2.1.2.2 Monthly Status

The Contractor shall prepare and present to the NASA/GSFC COTR monthly status via a written report. The report shall be a summary presentation of the period's progress, problem areas, and activities on-going and planned. The Contractor shall generate a list of significant milestones that will enable the NASA/GSFC COTR to ascertain program progress.

2.2 Reviews and Meetings

2.2.1 Technical Interchange Meetings (TIM)

The Contractor shall plan for informal, face-to-face technical interchange meetings to be held at the Contractor facilities. These TIMs shall support review and coordination of technical issues including, but not limited to, parts, test plans, test procedures, software changes, design modifications, and design analyses. The TIM meeting notice shall be seven (7) calendar days in advance of each meeting.

2.2.2 Contract Initiation Meeting

The Contractor shall organize and present a Contract Initiation Meeting (CIR) to a GSFC Review Team at the Contractor's facility soon after contract award within the timeframe specified in the contract. The purpose of the meeting is to

1. Allow the Contractor to refine and expand upon information provided in the Contractor's proposal.
2. Allow GSFC refine, clarify, and expand upon information presented to the Contractor as part of the RFP package.
3. Discuss detailed near term schedules and general long term schedules.
4. Discuss near term technical efforts (Contractor and sub-Contractor).
5. Discuss near term risks.
6. Facility tour.

2.2.3 Preliminary Design Review (PDR)

The Contractor shall organize and present a Preliminary Design Review to a GSFC Review Team at the Contractor's facility on a date defined in the contract. The Contractor shall time this review such that initial process development, subscale development testing and piece part testing, preliminary design activities, and subcontractor contacts are completed. The Contractor shall demonstrate overall conformance of the requirements specified in the Global Precipitation Measuring Mission Project Propellant Tank Performance Specification 422-PROP-SPEC-002 and this Statement of Work during this review. This Contractor shall cover programmatic, technical, test and verification, and quality assurance topics as a part or this review. The Contractor shall provide an opportunity for GSFC to review drawings and analyses available at the time of the review.

The Contractor shall provide to GSFC a Preliminary Design Review Presentation Package and all other required deliverable data two weeks prior to the review. For a description of this package see the Data Items List (DILS) which is a separate attachment to the contract.

2.2.4 Critical Design Review (CDR)

The Contractor shall organize and present a Critical Design Review to a GSFC Review Team at the Contractor's facility on a date defined in the contract. The Contractor shall time this review such that all development efforts and analyses have been completed and are documented in at least draft form. All qualification or flight tank manufacturing drawings must exist in draft form and all drawings of piece parts scheduled for fabrication within four weeks must be in final form. This review shall demonstrate overall conformance of the requirements specified in the Global Precipitation Measuring Mission Project Propellant Tank Performance Specification 422-PROP-SPEC-002 and this Statement of Work. This review shall cover programmatic, technical, test and verification, and quality assurance topics. This review shall also provide an opportunity to review drawings and all analyses required to be approved before the start of fabrication.

The Contractor shall provide to GSFC a Critical Design Review Presentation Package and all other required deliverable data two weeks prior to the review. For a description of this package see the Data Items List (DILS) which is a separate attachment to the contract.

2.2.5 Pre-Environmental Review (PER)

The Contractor shall organize and conduct a Pre-Environmental Review (PER) at the Contractor's facility before the qualification or flight tank environment test program begins. This review shall demonstrate overall conformance of the requirements specified in the Global Precipitation Measuring Mission Project Performance Specification 422-PROP-SPEC-002and this Statement of Work for this stage of the contract effort. This review shall cover programmatic, technical, test and verification, and quality assurance topics. This review shall also include a review of all test plans and procedures and all analyses required to approve the testing of the hardware.

2.2.6 Pre-Ship Review (PSR)

The Contractor shall hold a Pre-Ship Review at the Contractor's plant at the completion of verification tests and prior to shipment of the hardware to GSFC. A PSR shall be held prior to the delivery of each hardware item. A Data Delivery Package (reference 3.2.4) shall be presented for review at each PSR.

2.3 Documentation

2.3.1 General

The Contractor shall ensure the generation and delivery of all documentation as called for in the Contract. The Data Items List (DILS) is a separate attachment to the contract and is a complete list and description of the various documentation items.

In addition to that documentation specifically called for in the Contract, upon request by the NASA/GSFC COTR, the Contractor shall make available a copy of any document or data generated during this contract performance for review by the GSFC at either the Contractor's facility or via the internet. This includes, but is not limited to, technical reports and memorandums, drawings, schematics, studies, analyses, parts and materials data, test data, alerts, etc.

2.3.1 Action Item List

The Contractor shall prepare and maintain an Action Item List according to the instructions in the DILS.

2.3.2 Schedules

The Contractor shall prepare and maintain a Program Schedule according to the instructions in the DILS. Prepare and maintain a detailed Near Term Schedule according to the instructions in the DILS.

2.3.3 Engineering Documentation

As a result of process development and engineering analyses of the detailed design and subsequent fabrication, assembly, test, and inspection of the propellant tanks, the Contractor shall produce the technical documentation summarized below. Contractor format is suitable for this documentation. The Contractor shall annotate the review package materials if the presentation materials require additional clarification. For a complete list and description of the various documentation items, see the Data Items List (DILS) which is a separate part of this contract.

2.3.4 Interface Control Document (ICD)

The Contractor shall provide a document or documents that define, in detail, all performance, functional, environmental specifications, and all mechanical interfaces. The Contractor shall include an interface control drawing as part or the interface control package.

2.3.5 Drawing Package

The Contractor shall provide a drawing package that includes, but is not limited, to all mechanical assembly and interface drawings.

2.3.6 Preliminary Design Review Presentation Package

The Contractor shall provide a Preliminary Design Review (PDR) presentation package two weeks prior to the review. The Contractor shall address in the PDR data package all program management, design, analysis, manufacturing, test, and quality assurance activities outlined in this SOW and the Global Precipitation Measuring Mission Project Performance Specification 422-PROP-SPEC-002 in sufficient detail to ensure that the proposed design conforms to all requirements and is ready for fabrication to begin.

2.3.7 Development Report

The Contractor shall document the development efforts for the GPM tank in the Development Report. The goal of the report is to capture the significant steps taken in the development of the GPM tank. The Contractor shall include less detail and data than is typical for a test report or processing procedure but more than is typical for an executive summary.

2.3.8 Process and Manufacturing Development

Special processes and manufacturing techniques may be developed by the Contractor during the development of the GPM tank. These special processes would include scaled up or modified versions of the GSFC aluminum treatment process or other processes such as for cleaning and storage of sensitive parts. In-process testing would be included in this category. The Contractor shall include information describing these special processes in the Development Report.

2.3.8.1 Development Tests

The Contractor shall document all tests performed during the development phase of the GPM tank. Development testing may include but not be limited to weld development, contact angle testing, safe life coupon testing, and bubble point testing.

2.3.9 Verification Test Plan

The Contractor shall generate and deliver the Verification Test Plan which describes the verification tests the Contractor shall perform tests to fulfill the requirements in 422-PROP-SPEC-002. Verification tests are used to demonstrate acceptable performance over the specified range of performance requirements, measure performance parameters and reveal inadequacies in manufacturing and assembly such as workmanship or material problems.

2.3.10 Verification Test Procedures

The Contractor shall generate Verification Test Procedures. The verification procedures shall be step-by-step instructions for performing tests outlined by the Verification Test Plan. The procedures shall define the environmental conditions for the tests, required equipment and facilities, test constraints, use of diagnostic or performance test software, operating conditions, tolerance on all input stimuli, data to be recorded and pass/fail limits. Test procedures shall also include Safe-to-Mate procedures to verify that GSE can safely be mated to interfaces and that interfaces are safe to accept mating with the GSE.

Verification test procedures shall be Contractor controlled documents and shall indicate all changes made after the initial release for review to NASA.

2.3.11 Contamination Control Plan

The Contractor shall provide a Contamination Control Plan to GSFC for review. The Contractor shall include details from raw materials through delivery of the finished flight item to GSFC. The Contractor shall include recommendations to GSFC for contamination control of the flight tank after receipt by GSFC.

2.3.12 Fracture Control Plan

The Contractor shall furnish their Fracture Control Plan to GSFC for review.

2.3.13 Range Safety Compliance Document

The Contractor shall document its compliance with AFSPCMAN 91-710v3, 45th Space Wing Policy Letter, 23 NOV 1993, JMR-002A, and JERG-0-001. The Contractor shall support GPM project interactions with launch site safety personnel. The document will be considered preliminary by GSFC until all significant range safety issues related to this document have been resolved.

2.3.14 Qualification Test Report

The Contractor shall provide the qualification test report that demonstrates the design is qualified for space flight.

2.3.15 Tank Operational Constraints Document

The Contractor shall supply a document that provides GSFC with at least the following information to prevent unintentional damage to the flight hardware: maximum water and gas flow rates for testing, maximum and minimum storage temperature and humidity, maximum propellant loading and offloading flow rates, maximum IPA pressure, compatible fluids, and allowable pressurization and depressurization rates. Preliminary Tank Operational Constraints Document shall be presented at CDR.

2.3.16 Damage Control Plan

Contractor shall provide a damage control plan in accordance with Section 5.2.10 of ANSI/AIAA S-081A-2006 to GSFC for review.

2.4 Notification to NASA/GSFC CO and COTR

The Contractor shall notify the NASA/GSFC Contracting Officer's Technical Representative at least seven (7) calendar days in advance of all mandatory hardware inspections, test activities, and deliveries at either the Contractor's or a sub-Contractor's facility to allow timely participation by the NASA/GSFC Quality Assurance personnel.

3.0 Engineering

3.1 General Requirements

The Contractor shall perform analyses of the technical and environmental requirements specified in the Global Precipitation Measuring Mission Core Spacecraft Propulsion Subsystem Propellant Tank Specification 422-PROP-SPEC-002 to ensure NASA/GSFC personnel are able to use the delivered hardware. The Contractor shall assume fill fractions of 10%, 25%, 50%, 70% (nominal), and 96% at 20C for analyses sensitive to fill fraction.

3.2 PMD Design, Analysis, and Test

The Contractor shall design a PMD to meet or exceed all requirements documented in 422-PROP-SPEC-002. The Contractor shall perform and document a PMD analysis to show that the PMD provides gas free propellant delivery under all mission phases and meets all of the other performance requirements documented in 422-PROP-SPEC-002. Prior to arriving at the preferred configuration a number of options and configuration trades will be performed by the Contractor. The Contractor shall document this configuration selection process Bubble points, frictional pressure drops, and performance margins of the PMD on the ground and under each mission phase shall be analyzed and documented. Preliminary PMD performance analysis shall be presented at PDR. The Contractor shall provide detailed analyses for the specific cases documented in the table below. In addition, the Contractor shall provide a documented analytical model of the PMD. During the PMD design phases, the Contractor shall establish the gas-free liquid flow capacity of the PMD for its intended zero-gravity environment and

shall calculate its capacity under one earth gravity. The Contractor shall perform EOL residuals analysis.

GSFC shall develop a table of specific tests cases with detailed information including the acceleration level, delta V, and expected fuel fraction to the analyst for use in PMD and other tank analyses. A preliminary set of test cases is included in this SOW as Table 1. GSFC may modify the specific test cases based on Contractor recommendations.

Table 1. PMD Maneuver Performance, Test Cases

	Case 1	Case 2	Case 3	Case 4	Case 5
Event	Liftoff through separation from launch vehicle	Tip-off correction (separation event momentum unloading)	Drag makeup using aft thrusters including ACS firing	Delta-V during drag make up + ACS thruster firing	Post yaw maneuver settling
Temperature range (°C)	20C	20C	20C	20C	20C
Pressure range (psig)	Nominal (339.4 psi)	Nominal (339.4 psi)	–BOL=339.4	–BOL=339.4	–BOL=339.4
BOL Fill Fraction range (kg)	70%	70%	96%,70%, 50%	96%,70%, 50%	96%,70%, 50%
Remaining propellant range	100%	100%	100%, 50% 10%	100%, 50% 10%	100%, 50% 10%
Event duration	AR	AR	AR	AR	AR
Engine & thrusters firing	none	0 to 4 ACS thrusters, short on-pulses	4 Delta V thrusters 0 to 4 ACS thrusters,	4 Delta V thrusters 0 to 4 ACS thrusters,	none
Flow rate (kg/s)	0	AR	0.1204 max	0.1204 max	0
Max usage per maneuver (kg)		See spec	See spec	See spec	See spec
S/C angular rate X axis, rpm Y axis, rpm Z axis, rpm		See spec	See spec	See spec	See spec
Maximum S/C angular acceleration X axis, rad/sec^2 Y axis, rad/sec^2 Z axis, rad/sec^2		See spec	See spec	See spec	See spec
S/C linear acceleration X , g's (range) Y, g's (max.) Z , g's (max.)		See spec	See spec	See spec	See spec
Assumptions					

NOTE: See Spec for typical 5 lbf thruster performance.

3.2.1 Porous Element Bubble Point Test

The Contractor shall obtain bubble point data for aluminum wetted with hydrazine over the range of hole sizes that porous elements within the PMD might use. The Contractor shall include a range of hole sizes in the test whose area is a minimum of $\pm$ 100% of a nominal estimated area. The Contractor shall conduct the test on flight like aluminum alloy exposed to the same processes that the flight porous elements might encounter.

3.2.2 PMD Assembly Bubble Point Test

The Contractor shall bubble point test the PMD at the assembly level and with the PMD installed in the drain end of the tank with a test fluid. The Contractor shall obtain the data via test in one Earth gravity per Contractor written, NASA approved procedure. The Contractor shall also be required to certify performance in zero gravity and provide analyses and a statement of the calculated zero gravity performance margin with the PMD portion of the tank data package.

3.2.3 Pressure Drop Test

The Contractor shall conduct flow ΔP tests at the PMD assembly level and with the PMD installed in the drain end of the tank with a test fluid. The flow rates shall cover with margin the equivalent of the fuel flow rates encountered during the mission. The test fluid used for PMD flow testing will be the same as that used for tank flow rate testing. The fluid will be chosen for compatibility with the PMD and tank materials and treatments. The flow ΔP of the PMD shall be obtain via test in one Earth gravity per Contractor written, NASA approved procedure. The Contractor shall also be required to certify performance in zero gravity and provide analyses and a statement of the calculated zero gravity performance margin with the PMD portion of the tank data package.

3.2.4 Periodic Slosh Analysis

The Contractor shall perform a periodic slosh analysis. The periodic analysis is appropriate when the spacecraft undergoes constant acceleration (ΔV mode).

The Contractor shall deliver a spring/damper analytical model that describes the periodic motion of the propellant by providing input parameters such as the nominal levels of acceleration and fuel fraction. The model shall be constructed such that the spring/damper parameters expressed as a function of the input parameters. The model will be used by GSFC for internal use to obtain different spring/damper models by varying the model parameters.

3.2.5 Transient Slosh Analysis

The Contractor shall perform a transient slosh analysis. The transient analysis is appropriate during priming and during the phases of operation for which changes in forces on the propellant occur (launch vehicle separation and tumble, orbit raising maneuvers, yaw maneuvers, and post yaw maneuver resettling). A full CFD model will be developed to provide GSFC the CM location of the propellant, and time histories of forces and torques acting on the tank shell.

3.3 Trade Studies

3.3.1 Vacuum Loading Trade

The nominal thickness of the liner at its thinnest point is .030 inches per 422-PROP-SPEC-002. Composite overwrapped tanks of this thickness have been shown analytically to demise upon re-entry into the atmosphere. The selection of vacuum propellant loading may have an impact on the minimum thickness of the liner and the overall technical risk. The Contractor shall perform a trade study of a vacuum capable vs. a non-vacuum capable overwrapped tank for use by GPM. The Contractor shall assess the mass, cost, technical risk and schedule risk of each configuration.

3.3.2 Yielding, Non-yielding Liner Trade

The use of a non-yielding liner with an appropriately chosen overwrap fiber can be analyzed especially for flaw growth using classic techniques and thus may lower technical risk but may also have an unacceptable mass impact. The Contractor shall perform a trade study of a non-yielding vs. a yielding liner overwrapped tank for use by GPM. The Contractor shall assess the mass, cost, technical risk and schedule risk of each configuration.

3.4 Structural Analysis

A Structural Analysis shall be performed on the Flight Unit structure to ensure the capability to withstand and survive launch and ascent loads. A stress and fracture analysis shall also be performed. The effects of any thermal inputs shall be reflected in the analyses as appropriate. The Contractor shall meet the fatigue life requirement and stress rupture requirement per ANSI/AIAA S-081A-2006. The Contractor shall design the tank such that it has positive margins of safety due to the load requirements detailed in the tank specification. The results of these analyses shall be summarized in a Contractor format Mechanical Analyses Report that will be provided to the NASA GSFC COTR for review.

The Contractor shall use A-basis allowables determined based on tests data or from DOT/FAA/Ar-MMPDS-01 for metallic materials. The Contractor shall use A-basis allowables for composite materials based on tests data or found using the procedure stated in ANSI/AIAA S-081A-2006 Section 5.3. The Contractor shall use ANSI/AIAA S-081A-2006 to determine how fracture properties should be accounted for, methods on detrmining allowables for composites by test, and how to make those A-basis allowables, The Contractor shall provide procedures and test data produced during the development of this tank and shall include this information in a test report or as part of another deliverable report.

3.4.1 GPM Configuration Specific Structural Analyses

The Contractor shall perform structural analyses for the load environments detailed in 422-PROP-SPEC-002.

The structural analyses must account for the ~~SDO~~ GPM specific mounting arrangement of the tanks. The GPM interface must be considered non-rigid and thus deviates from the simple rigid mounting assumption which tanks are traditionally qualified to. The Contractor shall integrate the GSFC structural model of the tank interface structure known as the Propulsion Module (PM) with the Contractor's model of the tanks and determine the tank stresses and for use in providing inputs into the fracture analysis. GSFC and the Contractor shall establish FEM model transfer formats. The following are detailed tasks are required for implementing this analysis strategy:

1. GSFC shall provide the Contractor with a finite element model (FEM) model of the PM (only details of significance to the tank interface are required).

2. GSFC shall provide the Contractor with several quasi-static loading conditions representing the design limit loads.

3. The Contractor shall develop a detailed FEM of the tank, attach the tank to the GSFC- provided PM structural model, and obtain the stresses in the tanks for the GPM specific design.

4. The Contractor shall provide the Contractor developed tank FEM to GSFC.

5. GSFC shall perform the dynamic analysis and provide the Contractor with the frequencies of the PM with the Contractor tank model.

6. The Contractor shall use the results from the static analysis to establish the stresses due to the environments in the fracture histogram in performing the fracture analysis.

3.4.2 Stress Analysis

The Contractor shall perform a detailed and comprehensive continuum stress analysis. This analysis shall be conducted with the assumption that no crack-like flaws exist in the metal liner and there are no defects in the overwrap. The analysis shall determine stresses resulting from the combined effects of internal pressure, ground or flight loads, temperatures and thermal gradients. Both membrane stresses and bending stresses resulting from internal pressure and external loads shall be calculated to account for the effects of geometrical discontinuities, design configuration and structural support attachments. The analysis shall include the effects of adding stresses from restraints, manufacturing tolerances, test conditions, residual stresses and assembly stresses. Loads and pressures shall be combined by using the appropriate design limit or ultimate factors of safety on the individual load and pressure and comparing the results to material allowable.

The Contractor shall employ finite element methods or other proven equivalent structural analysis techniques using appropriate composite theories to analyze the liner, adhesive joints, composite overwrap, and mounts. The Contractor shall assess the effects of ply orientation, stacking sequence, and geometrical discontinuities. The Contractor shall use

the effect of variation in material thickness and its gradients as specified in the design documentation in calculating the stresses and strains in the liner and composite. The Contractor shall construct local structural models, as necessary, to augment the overall structural model in areas of rapidly varying stresses. The Contractor shall address plastic response under loading for plastically responding regions of the liner and shall include residual stresses. The Contractor shall deliver an electronic copy of the finite element model to GSFC per the DILS.

The Contractor shall maintain records of the stress analysis and shall include the input parameters, data, assumptions, rationales, methods, references and a summary of significant analysis results. The Contractor shall verify the analysis using test results. The Contractor shall provide a plot of stress versus position along the longitudinal axis of the tank for the launch conditions and MDP, proof and burst pressures. The Contractor shall provide GSFC with a summary table showing margins of safety for all stress analyses performed.

3.4.3 Safe Life Analysis

The Contractor shall perform a fracture mechanics analysis for those areas of the liner that remain elastic up to the proof pressure to show that the largest crack that could escape detection during NDI will not grow to leakage or fracture in four times the cycles specified in 422-PROP-SPEC-002 and detailed in a histogram to be provided by GSFC. Those areas of the liner that exceed the yield strain at any pressure up to, and including, the acceptance proof pressure shall be demonstrated by elastic/plastic tests per ANSI/AIAA S-081-2000 on uniaxial coupons to not leak or fracture in four times the cycles of the GSFC histogram.

3.5 GROUND LOADING ANALYSIS

The Contractor shall perform in-depth analysis and documentation of gas-free liquid priming during PMD tank ground loading to determine safe loading flow rates. The ground drainage analysis shall also be performed to determine expulsion efficiency.

4.0 Development

A number of manufacturing techniques may need to be developed, scaled up, modified or refined, prior to committing to the Development Tank manufacture and assembly. In-process verification technique development is considered part of manufacturing development. The contractor shall perform these efforts prior to committing to the Development Tank manufacture and assembly and prior to PDR.

4.1 ALUMINUM PROCESSING

Aluminum alloys (Al 6061 and 2219) have been shown in studies conducted under contract to GSFC to not be highly and consistently wettable when subjected to cleaning processes standard for titanium tanks. The Applicable Document WI-TBD(“aluminum treatment process”) has been used to create coupons scale aluminum items that are highly and repeatably wettable with hydrazine. The coupons have also been proven to retain these properties after long term exposure to hydrazine. Processed samples have

been shown to be sensitive to exposure to environments other than pure air, GN2, and pure water and have been shown to be sensitive to liquid or air born hydrocarbons.

4.1.1 Aluminum Coupon Processing

The Contractor shall produce 10 aluminum coupons of each alloy to be used in the tank whose consistent wettability with hydrazine is a requirement for the design. The Contractor shall include welded samples if wettability across weld is part of the design requirements.The Contractor shall then process the coupons and subject them to contact angle measurements with hydrazine. The Contractor shall submit the processing and testing procedures and data to GSFC for review. GSFC shall deem the contact angle results consistent if the scatter is $\pm$ 2 degrees for angle less than 20 degrees or $\pm$ 10% for angles greater than 20 degrees. The Contractor shall then submit the coupons to long term hydrazine aging followed by contact angle testing with the same success criteria as was established for the pre-aged samples. The Contractor shall submit the aging procedure to GSFC for approval and shall submit the test data for review. GSFC shall waive the hydrazine aging and post-aging contact angle tests if:

1. The process used by the Contractor is deemed by GSFC to be functionally identical to that documented in the GSFC WI-*** and the processed sample contact angle results are consistent and less than 7 degrees. Note that the GSFC process only applies to Al6061.

OR

2. The Contractor uses a process that has been shown via test data to produce consistent contact angle results in the desired range after long term hydrazine aging.

4.1.2 Full Scale Aluminum Processing Development

The Contractor shall proceed to scaling up of the aluminum treatment process subject to GSFC approval.

4.1.2.1 Full Scale Samples

The Contractor shall design sample parts of a scale and form similar to those to be used in the flight tank. The Contractor shall develop a process which mimics the aluminum coupon processing but employs tools, equipment, and techniques consistent with the efficient treatment of larger piece parts.

4.1.2.2 Surrogate Contact Angle Test Fluid

The Contractor will be allowed to perform contact angle testing for process development and in-process testing if a suitable fluid can be found. The fluid must have contact angle characteristics that can be reliably correlated to those of hydrazine. The fluid must also be completely removable from the surface such that the surface wettability properties and hydrazine compatibility properties are not compromised. The Contractor shall obtain GSFC approval prior to the use of the hydrazine surrogate fluid.

4.1.2.3 In-Process Testing Methods

The Contractor shall develop techniques to verify that the properties achieved after initial aluminum processing have been maintained as other processes and storage have been applied.

4.1.2.4 Develop Air Born Hydrocarbon Limits

The Contractor shall develop criteria for acceptable hydrocarbon exposure limits (concentration and total time) for hardware which is sensitive to hydrocarbon contamination.

4.1.2.5 Storage Methods for Piece Parts, Subassemblies, and Assemblies

The Contractor shall develop storage methods for tank piece parts, subassemblies and assemblies which are deemed sensitive to contamination or exposure to environments.

4.1.2.6 Heater and Thermal Component Bonding

The Contractor shall develop and demonstrate a method to bond heaters and other thermal components. The Contractor shall document the method or methods via a detailed procedure.

4.1 Weld Process Qualification

The Contractor shall qualify the welding process on a representative full-size ring. The qualification and full scale tank welds shall be left in the “as-welded” condition.

5.0 Hardware Manufacture and Deliverables

5.1 General

The Contractor shall manufacture and test hardware to meet the requirements of the Global Precipitation Measuring Mission Core Spacecraft Propulsion Subsystem Propellant Tank Specification 422-PROP-SPEC-002. The Contractor shall deliver all flight hardware and lifting GSE less than 24 months after contract award..

5.2 Development Tank

The Contractor shall produce a development tank which will be substantially similar to the flight tank in terms of processes used in manufacture and in terms of configuration. The external interface will be such that the development tank can be used for fit checks and installation checkout (test equipment and flight propulsion module). The Contractor may expose the development tank to a number of tests but shall also run a full and documented ATP. The Contractor shall use the development tank to verify the heater and thermal component installation process. The Contractor shall clearly mark the development tank as non-flight. The Contractor shall deliver the development tank to GSFC.

5.3 Qualification Tank

The Contractor shall produce a Qualification tank which will be identical in all ways to flight unit. The Contractor shall install flight heaters (if any used for flight) or close approximations per the Contractor developed process. The Contractor shall burst the qualification tank as part of the qualification test program. Portions may be removed by the Contractor for post failure inspections. The Contractor shall deliver the qualification tank to GSFC upon completion of all qualification efforts.

5.4 Flight Tank

The Contractor shall produce a flight tank and deliver it to GSFC which fulfills the requirements of the Specification, this SOW, and the governing contract. The Contractor shall install the flight heaters and other thermal hardware prior to delivery as a costed option upon request of GSFC. The Contractor shall deliver the flight tank prior to completion of the qualification test program if requested by GSFC.

5.5 Tank Covers

The Contractor shall design, produce, and deliver three sets of tank covers per ANSI/AIAA S-081A-2006. One of the sets of tank covers shall be installed on the flight tank during delivery.

5.6 Aluminum Liner

Identify appropriate attrition spares for the liners. The Contractor shall fabricate all liners from the same lot of material. The Contractor shall produce the Qualification liner and Flight liner using identical processes and during the same time frame.
Establish and inspect for surface finish based on optimal for bonding

5.7 Welding

The Contractor shall perform all welds per GSFC approved process(es). The Contractor shall produce a complete weld qualification ring prior to performing the closeout weld of the development, qualification, or flight tanks. The Contractor shall allow only certified welders to perform critical welds for the development, qualification, or flight tanks.
The Contractor shall place max overbead and neutral axis contour deviation requirements on the weldment drawing. The Contractor shall establish and inspect for surface finish based on criteria for optimal for composite bonding. The Contractor shall inspect the tank interior weld zone after overwrap with a boroscope if the tank design permits such an inspection to be performed with minimal risk. The Contractor shall use digital documentation of interior weld inspections.
The Contractor shall submit all close out weld repairs for approval by GSFC prior to performing the repair. GSFC may reject the repair request or may require additional offline tests prior to approval.

5.8 Composite Overwrap

The Contractor shall perform all composite overwrapping via qualified and approved processes. The Contractor shall establish liner internal pressure during winding and curing, and shall monitor pressure and temperature of liner during all phases and after cool down. GSFC may request in-process data from the overwrapping operations. The Contractor shall perform incoming inspection tests for adhesives to be used on the development, qualification, or flight tanks to characterize time/temp effect on flow/mobility and set to end of gelation cycle.

5.9 Coupons and Samples

The Contractor shall preserve samples and coupons of materials used for lot acceptance and process control. These items may include but are not limited to fiber lot samples, resin samples (cured and uncured), adhesives, metallic coupons, heat treat coupons, galvanic barrier samples, weld coupons, and weld consumables.

5.10 Tank Lifting GSE

The contractor shall deliver certified tank lifting GSE to GSFC at the same time as the flight tank is delivered. The GSE may be in a separate shipping container from the tank. shall conform to the requirements of NASA Safety Standard for Lifting Devices and Equipment (NASA STD 8719.9 Standard for Lifting Device and Equipment) and MSC Safety Manual (Doc# 5405-048-98). The Contractor shall ship the GSE certification along with the GSE.

6.0 Quality Assurance

6.1 General Requirements

6.1.1 Quality Assurance Plan/Manual

The Contractor shall implement a Quality Management System that meets the intent of the requirements of American National Standards Institute (ANSI)/ISO/ American Society for Quality (ASQ) Q9001 (1994 or 2000 version) or equivalent. GSFC shall be notified of any changes to the QA program.

6.1.2 Surveillance of the Contractor

The work activities and operations of the Contractor, subcontractors, and suppliers are subject to evaluation, review, survey, and inspection by GSFC representative.

The Contractor shall provide the GSFC representative with documents, records, equipment, and workings areas within their facilities that are required by the representative to perform their overview activities.

6.1.2.1 Government Source Inspection

The Government may elect to perform inspections at a supplier's plant. The following statement shall be included on all procurement documents: "All work on this order is subject to inspection and test by the Government at any time and place".

The Government quality representative who has been delegated NASA quality assurance functions on this procurement shall be notified immediately upon Contractor receipt of any supplier / subcontractor orders. The Government representative shall also be notified 48 hours in advance of the time that articles or materials are ready for inspection or test.

6.1.2.2 Contractor Source Inspection

The Contractor shall ensure that its procurement documents impose the applicable requirements on subcontractors and other suppliers. The subcontractor and other suppliers shall in turn impose the requirements on their procurement sources.

The Contractor shall perform source inspection at the subcontractor's or supplier's facilities in accordance with the procurement documentation or when one or more of the following conditions exist:

- In process, end item controls, or tests that are destructive in nature prevent the developer from verifying quality after delivery to the developer's facility.
- It is not feasible or economical for the Contractor to determine the quality of procured articles solely by inspections or tests performed at the Contractor's facility.
- Qualification tests are to be performed by the subcontractor or supplier.
- Products are shipped directly from the source to NASA, by-passing the Contractor's inspection facilities.

6.1.2.3 Government Mandatory Inspection Points (MIPs)

The Contractor shall submit a list of recommended mandatory inspection points. GSFC or its representative will perform as a minimum the following MIPs listed below. GSFC may request additional MIPs if a specific process prohibits inspection at a later time.

- Dye Penetrant Inspection prior to close-out weld
- Inspection and photographic documentation of PMD prior to close-out weld
- Rework Inspection
- Pre-Ship Inspection / Data Review

GSFC reserves the right, after review of the Contractor's inspection points, to add mandatory inspection points to the manufacture of the propellant tanks.

6.1.3 Configuration Management

The Contractor's Configuration Management (CM) system (available for review on request) shall control the design and hardware by means of drawings, specifications, and other documents and shall ensure all applicable changes are reviewed in a systematic

manner to determine the validity and impact on performance, schedule and cost. The Contractor's Configuration Management system shall have a change classification and impact assessment process that ensures Class I changes are forwarded to the CO for approval prior to release/incorporation. Class I changes are defined as changes that affect form, fit, function, external interfaces, or requirements as stated within this document and 422-PROP-SPEC-002.

All other changes are considered to be Class II changes and shall be controlled and dispositioned by the Contractor. All Class II changes shall be provided monthly to the COTR for review purposes. NASA/GSFC reserves the right to review all Class II changes for technical content to ensure the proper classification has been assigned. Any flight item that is found to be non-compliant with the quality, workmanship and performance requirements of the contract shall be dispositioned via a waiver or MRB, unless the affected item is reworked to restore compliance or is replaced with a fully compliant item. The Contractor shall submit Waivers and MRB's to the COTR for final approval.

A Contractor QA representative shall be a member of the Configuration Control Board. The QA activities shall be defined in the Configuration Management Plan and described in detail in the QA Plan. Related portions of the plans shall be cross-referenced.

6.1.4 Anomaly Reporting

The Contractor shall begin the reporting and documenting of hardware anomalies to the COTR starting with the first Contract Initiation Meeting. Drops, bumps and object strikes of liner or tank will be considered anomalies. After the first pressurization cycle at the start of acceptance testing, the Contractor shall notify the COTR within 24 hours of each anomaly.

The Contractor's processes for review, disposition and approval of anomaly reports shall be described in their quality plan/manual or provided as a supplement document. In addition, the Contractor's anomaly reporting document shall describe the members of the Material Review Board (MRB) and Failure Review Board (FRB). The MRB and FRB shall include GSFC/ GPM participation. These processes shall ensure that positive corrective action has been taken to preclude recurrence and that appropriate audits and tests are performed to verify the implementation of the corrective action.

The Contractor shall routinely inform the GPM Project of MRB and FRB meeting schedules and agendas with sufficient notice to permit GPM Project participation if desired by GPM.

At the Contractor's facility, GSFC representatives may participate in MRB/FRB activities as deemed appropriate by Government management or contract.

The GSFC COTR reserves disapproval rights on MRB and FRB decisions. To assure process consistency, the Contractor shall provide the GPM Project on-line access to their GPM anomaly-reporting database.

The Contractor shall provide, as part of the monthly report, a list of all open anomaly reports and a separate list of the anomaly reports closed during the month. For each reported anomaly or nonconformance, there shall be a report that documents the investigation and engineering analysis needed to determine the cause and corrective actions to disposition the nonconformance, and identify any closed problem reports that do not have a definitive cause or corrective action. Reports shall be submitted to the NASA GSFC COTR for review and approval of the disposition.

The supplier shall establish and maintain documented procedures to ensure product that does not conform to specific requirements is prevented from unintended use or installation. This control shall provide for identification, documentation, evaluation, segregation (when practical), disposition of nonconforming product, and for notification to the functions concerned.

6.1.5 Damage Control Plan and Reporting

The Contractor shall provide a Damage Control Plan according to the instructions in the DILS. The Contractor shall report possible, suspected, or confirmed damage during the weekly status meetings and shall maintain a record of incidents per contractor internal practice.

6.2 System Safety Requirements

The Contractor shall supply detailed descriptions of the design, test, operation and inspection requirements for all flight hardware and materials, ground support equipment, and their interfaces necessary for a valid identification, assessment, control and mitigation of documented hazards. This includes technical information concerning hazardous and safety critical equipment, systems, operations, handling and materials. For all identified hazards, the Contractor shall also document hazard controls, verifications and tracking methods.

The Contractor shall provide technical support to the GPM Project for safety working group and technical meetings as necessary in conjunction with TIMs.

6.3 Reliability Requirements

The Contractor shall prepare and conduct the following set of reliability analyses.

6.3.1 Failure Modes and Effects Analysis

The Contractor shall perform a Failure Modes and Effects Analysis (FMEA) in accordance with MIL-STD-1629, “Procedures for Performing an FMEA”. The FMEA shall identify failures at the functional level and address attendant consequences. This analysis shall be provided to the NASA COTR for review.

6.3.1.1 Limited-Life Items

The Contractor shall identify and manage limited-life items. Limited-life items include all hardware that is subject to degradation because of limited shelf life or expected operating times or cycles such that their expected useful life is less than twice the required life when fabrication, test, storage, and mission operation are combined.

The GPM Project COTR shall approve the use of an item whose expected life is less than twice the mission design life.

6.3.1.2 Reserved

6.4 Ground Support Equipment (GSE)

Mechanical and electrical Ground Support Equipment (GSE) and associated software that directly interfaces with flight deliverable items shall be assembled and maintained to mitigate potential risk to flight hardware. Parts and materials selection and reporting requirements are exempted as long as deliverable flight item contamination requirements are not compromised. However, all GSE interfaces to flight hardware shall be flight quality (e.g., connectors, baseplates, etc.).

6.5 Design Verification Requirements

6.5.1 Verification Requirements

The Contractor shall implement a program to verify all requirements specified in the Global Precipitation Measuring Mission Project Performance Specification 422-PROP-SPEC-002.

The Contractor shall provide a verification matrix defining the method of verification for each specific requirement of this contract. Verification methods shall include:

Inspection: Designated as (I) and represents inspection of the physical hardware by a customer appointed qualified inspector for compliance.

Analysis: Designated as (A) and represents documentation of performance or function through detailed analysis using all applicable tools and techniques.

Test: Designated as (T) and represents a detailed test of performance and/or functionality throughout a properly configured test setup where all critical data taken during the test period is captured for review.

In-process production evaluation tests, and environmental stress screening tests shall also be considered to be verification tests.

6.5.2 Analysis / Trending / Reporting Of Test Data

The Contractor shall properly record, maintain and analyze test information during the normal test program to assess performance and flight worthiness and to aid in the identification and analysis of flight hardware failures and problems.

The Contractor shall also perform trend analyses to track measurable parameters that relate to performance stability and repeatability. Selected parameters shall be monitored for trends starting at component acceptance testing and continuing through the system integration and test phases. These parameters shall be compiled in a Trended Parameters List (TPL).

The reports shall be delivered as part of the Data Delivery Package and presented at formal technical reviews as appropriate.

6.6 Workmanship Standards and Processes

6.6.1 Workmanship: Use of Alternate Workmanship Standards

GSFC recognizes that the Contractor may have an established workmanship program equivalent to the specific standards cited herein. In these instances, the Contractor may use existing standards upon review and approval by the GPM Project COTR. It must be established that the developer's workmanship program fully encompasses the specific requirements of this chapter. It is the Contractor's responsibility to list all deviations from the baseline workmanship standards and to provide data supporting their position/rationale.

6.6.2 Training and Certification of Contractor Personnel

All personnel performing work on flight hardware requiring a prerequisite set of skills and competency shall be certified as having completed the required training, appropriate to their involvement. Specific certifications and training are called out in the tank specification, in ANSI/AIAA S-080-1998, and in ANSI/AIAA S-081A-2006.

6.6.3 Hardware Handling, Cleaning And Packaging

The handling of flight hardware shall be performed by qualified personnel in accordance with approved procedures that address cleaning, handling, packaging, tent enclosures, shipping containers, bagging, and purging. Compatible packaging shall be selected so that hardware is not contaminated or otherwise degraded during shipping or storage. All personnel working on flight hardware shall be certified as having completed the required training and competency certifications prior to handling any flight hardware. This includes, but is not limited to, workmanship and clean room awareness courses.

6.6.4 Workmanship Requirements

The Contractor shall perform all work in accordance with the workmanship requirements of AFSPCMAN 91-710v3 Air Force Space Command Manual 91-710, volume 3, Range Safety User Requirements Manual, Volume 3 – Launch Vehicles, Payloads, and Ground

Support Systems Requirements. The workmanship of the composite overwrap shall be in accordance with ANSI/AIAA S-081A-2006 (Space Systems – Composite Overwrapped Pressure Vessels (COPVs)).

6.6.5 GIDEP Alerts and Problem Advisories

Contractors shall keep sufficient selection and usage records for all flight parts and materials adequate to determine applicability of any issued Government Industry Data Exchange Program (GIDEP) alerts relevant to items used on GPM. The Contractor shall review and disposition all GIDEP Alerts for relevancy and impact. In addition, the Contractor shall review and disposition any NASA Alerts and Advisories provided to the developer by the GPM Project. Alert applicability, impact, and corrective actions shall be documented and status provided to the GPM Project on a monthly basis.

6.7 Materials, Processes and Lubrication Requirements

6.7.1 Materials Selection Requirements

6.7.1.1 Flight quality

To qualify material for flight use, the material must have a satisfactory flight heritage relevant to GPM requirements or meet the following applicable selection criteria as defined herein for:

- Vacuum outgassing
- Stress corrosion cracking (SCC)
- Lubrication requirements
- Manufacturing process selection
- Fastener integrity

6.7.1.2 Materials and Processes Identification List

The Contractor shall create and maintain a Materials and Processes Identification List (M&P) and shall review proposed materials and processes with the GPM GSFC COTR. An As-Built Materials List (ABML) shall be included as part of the end item data package.

6.7.1.3 Prohibited Materials

Pure Tin, Zinc, and Cadmium are not acceptable for flight use.

6.7.1.4 Material Availability

The Contractor shall certify the availability of critical materials prior to their inclusion into the design. Availability is defined as 100% margin on the quantity, flight quality, procurement lead times consistent with the schedule, and cost consistent with proposed estimates. A critical material is defined as a material for which no reasonable substitute material is available.

6.7.2 Vacuum Outgassing of Polymeric Materials

Only materials that have a total mass loss (TML) less than 1.00% and a collected volatile condensable mass (CVCM) less than 0.10% shall be approved for use in a vacuum environment. Material vacuum outgassing shall be determined in accordance with ASTM E-595. If a material exceeds these maximum limits, the Contractor shall be required to either replace with a compliant material or bring it into compliance via a vacuum bakeout, or to submit a Material Usage Agreement (MUA) for its usage.

6.7.3 Stress Corrosion Cracking of Inorganic Materials

Materials used in structural applications shall be highly resistant to stress corrosion cracking (SCC) as specified in **MSFC-STD-3029**. A Material Usage Agreement (MUA) and a SCC evaluation form shall be submitted, Contractor format acceptable, for each material usage that does not comply with the **MSFC-STD-3029** SCC requirements.

6.7.4 Process Selection Requirements

Materials and manufacturing process information shall be provided on the material list.

6.7.5 Fasteners

The Contractor shall comply with the procurement and test requirements for flight hardware and critical ground support equipment fasteners contained in 541-PG-8072.1.2, Goddard Space Flight Center Fastener Integrity Requirements. Traceability shall be maintained for every fastener lot.

6.7.6 Materials Procurement Requirements

Raw materials purchased by the Contractor and its developers shall be accompanied by a Certificate of Compliance and, where applicable, the results of nondestructive, chemical and physical tests. When requested, this information shall be made available to the NASA GSFC COTR for review.

6.7.7 Dissimilar Metals

To avoid electrolytic corrosion, dissimilar metals shall not be used in direct contact unless protection against corrosion has been provided in accordance with MIL-STD-889. The Contractor shall submit a written request to deviate from this requirement, which shall be approved by the GSFC COTR.

6.7.8 Heat Treatment

Metal parts of the tank shall be heat treated in accordance with NASA approved Contractor procedure. All tank welds shall be aged and stress relieved.

6.7.9 Welding

Welding shall be performed and inspected per Contractor/NASA approved procedure. Control of weld filler material shall also be per Contractor and NASA approval.

6.7.10 Embrittlement Control

The Contractor shall identify and control in the design, fabrication and operation of the tank all known embrittlement mechanisms applicable to the materials used for the liner, fiber, or resin.

6.7.11 Fungus Inert Material

All materials used in the tank shall be fungus inert in accordance with MIL-STD-810F.

6.7.12 Corrosive Metals

All materials used in the tank shall be corrosion resistant.

6.7.13 Interchangeability

Each tank assembly shall be directly interchangeable physically and functionally with other items of the same part number.

7.0 Contamination Control Requirements

The Contractor shall establish the specific cleanliness requirements to minimize performance degradation and delineate the approaches to meet the GPM Project requirements. The Contractor may use a combination of standard and unique procedures to meet the cleanliness requirements.

8.0 Handling, Storage, Packaging, Preservation, and Delivery

Products shall be stored, preserved, marked, labeled, packaged, and packed to prevent loss of marking, deterioration, contamination, excessive condensation and moisture, or damage during all phases of the program. Stored and stocked items shall be controlled in accordance with documented procedures and be subject to quality surveillance.

The tank shall be marked in accordance with MIL-STD-130L, and shall include but not be limited to the following:

1) Contractor Part Number
2) Contractor Name
3) Contractor Serial Number
4) Contract Number
5) Unit Name
6) Weight

Contractor is responsible for providing an acceptable shipping container that protects the hardware appropriately.

While in a shipping container, each propellant tank shall be wrapped in a non-ESD-generating vapor barrier with redundant maximum humidity indicators. Mounting

surfaces and ports shall be protected with pads that shall not cause tank deterioration. Each tank port shall be protected from contamination entering the tank. Each tank shall be wrapped in a clean non-static bag retained in place by pressure-sensitive tape applied only to the bag surface itself. A second sealed plastic bag shall be placed over the inner bag. A legible tank identification card shall be taped to the outer surface of the inner bag so that the card is readable without opening the outer bag.

The shipping container shall also include shock and humidity indicators if necessary and shall be capable of prolonged shipping conditions. The Contractor shall document what action NASA GSFC is to take if the sensors are tripped when hardware arrives at the NASA GSFC receiving area. A copy of this document shall be included with shipping documentation.

By executing the act of product shipment, the Contractor certifies that the product complies with all contract requirements. Prior to shipping, quality assurance personnel shall ensure that:

- Fabrication, inspection, and test operations have been completed and accepted.
- All products are identified and marked in accordance with requirements.
- The accompanying documentation (developer's shipping and property accountable form) has been reviewed for completeness, identification, and quality approvals.
- Evidence exists that preservation and packaging are in compliance with requirements.
- Packaging and marking of products, as a minimum comply with Interstate Commerce Commission rules and regulations and are adequate to ensure safe arrival and ready identification at their destinations.
- The loading and transporting methods are in compliance with those designated in the shipping documents.
- Integrity seals are on shipping containers and externally observable shock or humidity monitors do not show excessive environmental exposure.
- In the event of unscheduled removal of a product from its container, the extent of re-inspection and retest shall be as authorized by NASA or its representative.
- Special handling instructions for receiving activities, including observation and recording requirements for shipping-environment monitors are provided where appropriate.

The Contractor’s quality assurance organization shall verify prior to shipment that the above requirements have been met and shall sign off appropriate shipping documents to provide evidence of this verification. The Contractor shall ship Freight On Board (F.O.B.) Destination. The Contractor has the responsibility for any damage incurred during shipment.

APPENDIX A: Abbreviations and Acronyms

ABBREVIATION/ ACRONYM	DEFINITION
ABML	As-Built Materials List
ABPL	As-Built Parts List
ADC	After Date of Contract
AIP	Assurance Implementation Plan
ANSI	American National Standards Institute
ATP	Acceptance Test Procedure
BSP	Board Support Package
CAD	Computer Aided Design
CAGE	Commercial and Government Entity
C&DH	Command and Data Handling
CDR	Critical Design Review
CFD	Computational Fluid Dynamics
CIR	Contract Initiation Meeting
CM	Configuration Management
CO	Contracting Officer
COTR	Contracting Officer's Technical Representative
CVCM	Collected Volatile Condensable Mass
DPA	Destructive Physical Analysis
EO	Engineering Order
ESD	Electrostatic-Discharge
ETU	Engineering Test Unit
FCIP	Failure Control Implementation Plan
FMEA	Failure Modes and Effects Analysis
FOB	Freight On Board
FRB	Failure Review Board
FU	Flight Unit
GIDEP	Government/Industry Data Exchange Program
GSE	Ground Support Equipment
GSFC	Goddard Space Flight Center
GSI	Government Source Inspection
ICD	Interface Control Document
MAR	Mission Assurance Requirements
MIL	Materials Identification List
MIP	Mandatory Inspection Point
MRB	Material Review Board

ABBREVIATION/ ACRONYM	DEFINITION
MRR	Manufacturing Readiness Review
MUA	Materials Usage Agreement
NDE	Non-destructive Examination
NSPAR	Non Standard Parts Approval Request
PDR	
PEMs	Plastic Encapsulated Microcircuits
PER	Pre-Environmental Review
PIL	Parts Identification List
PIND	Particle Impact Noise Detection
PMD	Propellant Management Device
PSR	Pre-Ship Review
PWB	Printed Wiring Board
QA	Quality Assurance
QCM	Quartz Crystal Microbalance
RFP	
ROM	Read-Only Memory
R&QA	Reliability and Quality Assurance
SCC	Stress Corrosion Cracking
SCM	Software Configuration Management
S/C	Spacecraft
SEE	Single-Event Effects
SOW	Statement of Work
SUROM	Startup Read-Only Memory
TML	Total Mass Loss
TID	Total Ionizing Dose
TIM	Technical Interchange Meeting
TO	Technical Officer
TPL	Trended Parameters List
WVR	Waiver

APPENDIX B: GPM Material Usage Agreement Form

<table>
<tr><td colspan="3">MATERIAL USAGE AGREEMENT (MUA)</td><td colspan="3">USAGE AGREEMENT NO.:</td><td>PAGE OF</td></tr>
<tr><td>PROJECT:</td><td>:</td><td colspan="3">ORIGINATOR:</td><td>ORGANIZATION:</td></tr>
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<tr><td colspan="6">RATIONALE:</td></tr>
<tr><td colspan="3">ORIGINATOR:</td><td colspan="2">PROJECT MANAGER:</td><td>DATE:</td></tr>
</table>

APPENDIX C: List of Referenced Documents

Applicable Documents

All referenced documentation identified in the SOW shall apply in the situations where they are specifically referenced. Where no revision date is given, the latest version applies

DOCUMENT NUMBER	TITLE
422-PROP-SPEC-002	Performance Specification: Global Precipitation Measuring Mission (GPM) Project Propulsion Subsystem Propellant Tank. July 2007
422	Mission Assurance Requirements (MAR) for Global Precipitation Measuring Mission (GPM). Rev. A 09/03/03
541-PG-8072.1.2	GSFC Fastener Integrity Requirements. 03/05/01
ANSI/ASQ9001-2000	Model for Quality Assurance Design, Development, Production, Installation, and Servicing. Aug 1991
NASA-STD-8739.7	Electrostatic Discharge Control. 12/15/97
S-311-M-70	Destructive Physical Analysis. Equivalent. 1/7/1990
NASA-STD-6001	Flammability, odor, off-gassing and compatibility requirements & test procedures for materials in environments that support combustion. 2/9/1998
MSFC-STD-3029	Multiprogram/project common-use document guidelines for the selection of metallic materials for stress corrosion cracking resistance in sodium chloride environments. 5/22/00
ASTM E-595	Standard test method for total mass loss and collected volatile condensable materials from outgassing in a vacuum environment. 10/1/03

Military Documents

AFSPCMAN 91-710v3	Air Force Space Command Manual 91-710, volume 3, Range Safety User Requirements Manual, Volume 3 – Launch Vehicles, Payloads, and Ground Support Systems Requirements (replaces EWR 127-1)
MIL-HDBK-17B	Plastics for Flight and Aerospace Vehicles
MIL-P-26536	Propellant, Hydrazine, High Purity
MIL-PRF-27401	Propellant, Nitrogen, Pressurizing Agent
MIL-PRF-27407B	Propellant, Helium, Pressurizing Agent
MIL-PRF-27415A	Propellant Pressurization Agent, Argon
MIL-STD-13OL	Identification Marking of U.S. Military Property
MIL-STD-2154	Inspection, Ultrasonic, Wrought Metals, Process For
MIL-STD-453C	Inspection, Radiographic

MIL-STD-464	Interfaced Standard Electromagnetic Environmental Effects Requirements for Systems
MIL-STD-810F	Environmental Test Method
MIL-STD-889B	Dissimilar Metals
MIL-STD-970	Standards and Specifications, Order of Precedence for the Selection of
MIL-STD-1540C	Test Requirements for Space Vehicles
MIL-STD-45662A	Calibration System Requirements
MIL-W-46132	Welding, Fusion, Electron Beam, Process for
45th Space Wing Policy Letter, 23 NOV 1993	Interim Safety Requirements for Design, Test, and Ground Processing of Flight Graphite Epoxy (Gr/EP) Composite Overwrapped Pressure Vessels (COPVs) at the Kennedy Space Center (KSC), Cape Canaveral Air Force Station (CCAFS), and Vandenberg Air Force Base (VAFB)
MIL-STD-1629	Procedures for Performing an FMEA. 11/24/1980
AFS	AF Range Safety Requirements

FEDERAL DOCUMENTS

TT-I-735	Isopropyl Alcohol
DOT/FAA/AR-MMPDS-01	Metallic Materials Properties Development and Standardization (MMPDS)

NASA Documents

JSC-SPEC-C-20C	Water, High Purity, Specification for
GSFC-S-313-009	Fluorescent Penetrant Test Method Requirements and Guidelines
GSFC-X-673-64-lE	Engineering Drawing Standards Manual
NASA Policy Directive 8710.3	NASA Policy for Limiting Orbital Debris Generation
NASA Safety Standard 1740.14	Guidelines and Assessment Procedures for Limiting Orbital Debris
GSFC WI Ttttttt	Wettable Aluminum 6061 Treatment Process
NASA STD 8719.9	NASA Safety Standard for Lifting Devices and Equipment ()
MSC Doc# 5405-048-98	MSC Safety Manual

GPM Documents

422-40-01-004	GPM Mission Assurance Requirements

aaaaaaaaa	“GPM Propulsion Subsystem Specification”
bbbbbbbb	“GPM Mechanical Systems Specification”
dddddd	“GPM Observatory Mass Properties Report”
eeeeeeee	“GPM Tank to Spacecraft Mechanical Interface Control Drawing”
ccccccccc	Environmental Verification Requirements
TBD	GPM Propulsion System Envelope Drawing
WI-TBD	Aluminum processing for wettability procedure

NASDA/JAXA Documents

JMR-002A	Launch Vehicle Payload Safety Standard (JAXA)
CFX-97010	Implementation Plan for System Safety Reviews (Non-JAXA Satellites)
JERG-0-001	Technical Standard for High-Pressure Gas Equipment for Space Use (JAXA) (April 1, 2004)

OTHER DOCUMENTS

ANSI/AIAA S-080-1998	Space Systems – Metallic Pressure Vessels, Pressurized Structures, and Pressure Components
ANSI/AIAA S-081A-2006	Space Systems – Composite Overwrapped Pressure Vessels (COPVs)
ASTM D1193-06	Standard Specification for Reagent Water
ASTM E595	Standard Test Method for Total Mass Loss and Collected Volatile Condensable Materials from Outgassing in a Vacuum Environment
AMS-QQ-A-250/11	Aluminum 6061-T6 Alloy Sheet & Plate, Aircraft Quality
IEST-STD- CC1246D	Product Cleanliness Levels and Contamination Control Program