



**NASA**  
**GODDARD SPACE FLIGHT CENTER**

**STATEMENT OF WORK**

**FOR**

**MECHANICAL INTEGRATED SERVICES AND TECHNOLOGIES  
(MIST)**

**FOR THE**

**APPLIED ENGINEERING AND  
TECHNOLOGY DIRECTORATE (AETD)**

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## INTRODUCTION

The National Aeronautics and Space Administration (NASA) was established to plan, direct, and conduct aeronautical and space activities for peaceful purposes for the benefit of all humankind. The operational aspects of NASA's work are divided among field installations around the country and involve research and development activities under the responsibility of four technical program offices at NASA Headquarters.

The Goddard Space Flight Center (GSFC) is located in Greenbelt, Maryland and reports to the Office of Science. The GSFC is chartered to expand the knowledge of the earth and its environment, the solar system, and the universe through observations from space. To this end, the GSFC's primary emphasis is in scientific investigation, in the development and operation of space systems, and in the advancement of essential technologies. In accomplishing this responsibility, the GSFC has undertaken a broad program of scientific research, both theoretical and experimental, in the study of space phenomena and earth sciences. The program ranges from basic research to flight experiment developments and from mission operations to data analysis.

Within the GSFC, the Applied Engineering Technology Directorate (AETD) plans, organizes, and conducts a broad range of technical research and development activities in support of science applications. The AETD is responsible for providing engineering expertise and support in the formulation, design, development, fabrication, integration, test, verification, and operation of components, subsystems, systems, science instruments, and complete spacecraft for multiple projects. The specific components, subsystems, systems, and science instruments are ultimately integrated into the spacecraft to form a science observatory. It is these observatories that are launched to fulfill the mission of the GSFC. The AETD comprises five engineering divisions: the Mechanical Systems Division (MSD), the Instrument Systems and Technology Division (ISTD), the Electrical Engineering Division (EED), the Software Engineering Division (SED), and the Mission Engineering and Systems Analysis Division (MESA).

To fulfill these responsibilities and ultimately achieve their missions, GSFC must acquire a wide range of engineering services in support of its divisions to implement the GSFC mission.

## **SCOPE OF WORK**

The purpose of this contract is to acquire engineering services and related services to MSD and related organizations throughout GSFC, as required, for the formulation, design, development, fabrication, integration, testing, verification, and operations of space flight and ground system hardware and software, including development and validation of new technologies to enable future space and science missions. The engineering areas of emphasis are multidisciplinary with concentration in the mechanical engineering areas of materials, structural analysis and loads, mechanical design, electromechanical design, thermal, contamination and coatings, manufacturing, and integration and test.

To this end, the Contractor shall provide on/off-site multidisciplinary engineering services, pursuant to task assignments issued by the Contracting Officer. These services shall include the personnel, facilities, and materials (unless otherwise provided by the Government) to accomplish the tasks.

Current engineering services provided rely on frequent face-to-face communication between the Government and its Contractors. This includes meetings with the task manager and with various organizations throughout GSFC. The amount and form of communication varies from task to task. It will be necessary for the Contractor's project managers and technical task managers to have the capability to attend frequent face-to-face meetings with Government personnel at the GSFC for a vast majority of the task orders to be issued in the future. The Contractor shall have the capability to conduct these communications without being unproductive and inefficient.

Tasks orders will be issued to perform services in all aspects of mission and instrument development and implementation for components, subsystems, systems, science instruments, observatories, launch, ground system, spacecraft, and suborbital craft (e.g., aircraft, sounding rockets, UAVs, balloons), including attached Space Station payloads, free-flying spacecraft, suborbital craft payloads, as well as ground support equipment, simulators, non-flight models, and prototypes; candidate, feasibility, and systems definition studies; project management; systems engineering; analysis; preliminary design; detailed design; non-flight and flight fabrication; assembly; integration; test and verification; test instrumentation; data systems management; launch, on-orbit and post-launch operations; research and technology unique to system development; parts and materials, technical facilities support, logistics, documentation; maintenance; sustaining engineering; configuration management; mission assurance; architectural trades, performance, cost, risk assessment, and systems safety.

## **I. GENERAL RESPONSIBILITIES**

The Contractor's responsibilities shall include the management of personnel, timely and effective implementation of task assignments, control and monitoring of contract and subcontract performance, management of scheduled deliveries, and timely and effective reporting to the Government. These responsibilities shall also include efficient cost management methods as well as procedures to ensure that the Government is aware of task assignment status and progress achieved.

The administration of the task assignments under this contract shall be handled via the Task Order Management Systems (TOMS) web-based software tool, to be provided by NASA's Goddard Space Flight Center. The Contractor shall ensure computer system compatibility with the TOMS software compatibility requirements at all times. TOMS shall be the primary tool for administration of tasks under this contract.

## **II. PERFORMANCE MEASUREMENT**

Performance-based statements of work/specifications will be used for establishing contract requirements. Therefore, each task assignment issued by the Contracting Officer will include, as a minimum, the following:

1. Statement of Work, including the requirements to be met, the standard(s) of performance/quality of work, and required deliverables (or other output)
2. Performance Specification (if applicable)
3. Applicable Documents (if required)
4. Period of Performance
5. Incentive Structure
6. Surveillance Plan
7. Contractor response evaluation criteria for purposes of technical recommendation for Contractor selection

The Contractor shall be required to adhere to the performance measurements detailed in each task assignment.

### **III. TASKS**

Services shall be required in one or more of the areas described in the scope above for any given task assignment. Services within the scope of this Statement of Work and specified in task assignments shall include, but not be limited to, the specific services delineated in the following sections.

## **FUNCTION 1 – Pre-Formulation and Formulation Services: Candidate, Preliminary Analysis, and Systems Definition Studies**

The Contractor shall provide engineering services for mission concept development that integrate the aspects of flight systems, ground systems, instrument systems, and launch systems.

In general, the Contractor shall:

1. Produce pre-formulation and formulation phase study inputs for spacecraft, suborbital craft, instruments, payloads, and ground systems
2. Develop mission needs (mission objectives, measurement concepts, and instrument concepts) and mission design (mission requirements, architectural design, and operations concepts).
3. Develop preliminary, relative cost and schedule estimates based on design alternatives, and identify and assess high-risk elements in designs
4. Document the history of design, qualification, flight experience, and modifications where existing components or subsystems are to be utilized
5. Identify interface requirements for pre-launch, launch, on-orbit servicing, or retrieval of flight hardware
6. Define interface engineering and management requirements
7. Prepare mission systems and operations documentation
8. Prepare requirements and specification packages that conform to applicable standards defined within task statement
9. Identify interfaces and prepare interface control documents
10. Provide technical inputs for problem-solving and/or design inputs in selected spacecraft, instruments, suborbital craft, ground system, and data disciplines
11. Analyze various reports (i.e., progress reports, technical reports, etc.) delivered by the GSFC mission Contractor(s) and provide recommendations to the project
12. Provide liaison and coordination services for project activities
13. Provide design services that include performance of preliminary design leading to a Preliminary Design Review (PDR) of the subsystems, components, and assemblies that comprise the instrument/spacecraft/platform/launch system/ground system.

## **A. Candidate Study Services**

The Contractor shall provide study services for the conceptual design and development of subsystems and systems, thereby participating in the identification of scientific objectives, mission requirements and technical concepts. Study products produced during this phase shall include, but are not limited to:

1. Strategic technology planning
2. Integration of joint missions, partnerships, and other collaborative efforts
3. Research, science, technology and cost trade studies
4. Candidate operations concepts
5. Candidate system architectures
6. Cost, schedule, and risk estimates
7. Research and technology unique to system development
8. Customer development support and outreach

## **B. Preliminary Analysis Study Services**

The Contractor shall provide preliminary analysis study services focusing on analyzing mission requirements and establishing mission architectures in order to demonstrate that a credible, feasible design(s) exist(s). The Contractor shall develop top-level requirements and evaluation criteria, identify alternative operations/logistics concepts, and identify project constraints and system boundaries. Study products produced during this phase shall include, but are not limited to:

### **1.0 Analysis Services Specific Tasks – The Contractor shall perform analysis services tasks, including but not limited to:**

- a. Preliminary system design of a feasible, but not necessarily optimum configuration.
- b. Assessment of technical risks, including identification of technical problems and the criticality of their solution to follow-on efforts; identification of those problems currently being addressed; and a judgment of effort and time likely to be necessary to find a practical solution.
- c. Identification of all recommended systems characteristics, including launch and control capability, tracking and data acquisition, facility considerations, and institutional base activities.
- d. Implementation plans, which include the identification of all major systems and subsystems.
- e. Preparation of the system design that forms the basis for implementing system development (hardware or software).

- f. Provide alternative design concepts including feasibility and risk studies, cost and schedule estimates, and advanced technology requirements.
- g. Prepare for and support the appropriate Phase A project and technical reviews and prepare Phase A project documentation as appropriate (see the NASA/SP-2007-6105 Rev1, NASA Systems Engineering Handbook).

**2.0 Documentation Specific Tasks – The Contractor shall document all results from the study in a Feasibility Study Report.**

**C. System Definition Study Services**

The Contractor shall provide system definition and preliminary design study services to establish and evolve the project baseline(s). These shall include:

**1.0 Analysis Services Specific Tasks – The Contractor shall perform system definition analysis services specific tasks, which may include but are not limited to the following:**

- a. Define system requirements, system budgets (e.g., mass, power, memory), error budgets, system/subsystem requirements, software requirements, ground support equipment requirements, and integration and test requirements.
- b. Identify all recommended system characteristics, defining the subsystem components and assemblies, identifying the required complement of flight and ground support equipment, specifying internal and external interfaces, and verifying that the recommended design approach's critical subsystems and components are within the state-of-the-art.
- c. Provide a formal flow down of project-level performance requirements to a complete set of system and subsystem design specifications for both flight and ground elements. Phase B baseline information shall be developed, including system requirements and verification requirements matrices, system architecture and work breakdown structures, operations concepts, "design-to" specifications at all levels, and project plans including schedule, resources, and acquisition strategies.
- d. Perform risk assessments of all critical elements and describe the risks and control methods. The knowledge and use of Probability Risk Assessment (PRA), Failure Modes and Effects Analysis (FMEA) and Fault Tree Analysis (FTA) is required and shall be performed in conjunction with the GSFC Safety and Mission Assurance Directorate.
- e. Prepare the system design that shall form the basis for implementing/developing the system (hardware or software); define the tasks and sequence of tasks that shall be performed to provide orderly technical development, design, review, interface, test, and integration of the system; and provide the required plans (modeling, analysis, and

simulation; configuration; logistics; information; software; verification; integration and test, etc.) for the effort.

- f. Identify areas where the design is not meeting requirements up front, such as not meeting Mission Assurance Requirements, or having critical suppliers that are not AS9100 or ISO9001 registered. Declare COTS items that are critical to the mission.
- g. Describe and document integrated mission architecture.
- h. Prepare for and support the appropriate Phase B project and technical reviews and prepare Phase B project documentation as appropriate (see the NASA/SP-2007-6105 Rev1, NASA Systems Engineering Handbook).

**2.0 Documentation Specific Tasks – The Contractor shall document all results from the study effort in a Definition Study Report.**

## **FUNCTION 2 – Implementation Phase Services – Mechanical Systems**

The Contractor shall provide services to design, analyze, develop, fabricate, assemble, unit test, system integrate, verify, mission integrate, deploy, and operate hardware and software on spacecraft, platform, and/or payload as defined by this Statement of Work. The Contractor shall have available a subject matter expert that will track technical procurements and ensure they meet specification. The implementation phase services shall include:

### **A. Materials Engineering**

The Contractor shall provide materials and processes engineering support for the development and implementation of materials and processes control programs for GSFC managed flight projects. Contractor materials and processes engineers shall assist GSFC project engineers with the selection and application of materials and processes, plan and supervise investigations or evaluations, provide general materials program management and assess the flight worthiness of all materials usage. This includes providing materials and processes engineering expertise to projects and designers in the form of consultation, guidance and review. This support will address reliability, product assurance, and quality assurance.

#### **1.0 Materials Assurance Engineering**

The Contractor shall provide materials engineering support for the development and implementation of materials assurance programs for GSFC managed flight projects. Contractor materials engineers shall assist GSFC project engineers with the selection and application of materials and processes, plan and supervise investigations or evaluations, provide general materials program management and assess the flight worthiness of all materials usage, in compliance with applicable mission Safety and Mission Assurance (SMA) requirements. This includes providing materials engineering expertise to projects and designers in the form of consultation, guidance and review. This support will address reliability, product assurance, and quality assurance. Individuals who perform inspections of printed circuit boards, printed wiring assemblies, or cable harnesses for acceptance for use in mission hardware shall be certified to the applicable workmanship or printed circuit board standard and all relevant GPRs and PGs.

##### **a. Document Reviews**

The Contractor shall review all material usage lists, materials processes and documentation associated with material applications. The Contractor shall prepare reports that identify differences between Contractor documentation and NASA requirements and recommend required changes. When needed, the Contractor shall provide all materials support required for the success of the project. The Contractor shall support review of all drawings and drawing notes to ensure minimum design and SMA requirements are specified.

**b. Material Usage Lists**

The Contractor shall review and recommend flight usage for material lists for GSFC managed flight projects in accordance with project requirements. The review process shall identify materials and their usage as standard or nonstandard and as compliant or noncompliant. Materials Usage Agreements shall be reviewed and approved or disapproved. The maintenance and distribution of material lists shall address requirements such as revision tracking and approval status.

**c. Facility Evaluations**

The Contractor shall evaluate GSFC and NASA Contractor Materials Engineering, processing and quality facilities for required equipment, processes, personnel training and capability for producing flight quality hardware. The Contractor shall prepare reports of findings and recommendations for bringing facilities into compliance with requirements. These evaluations shall be done in conjunction with the GSFC SMA Directorate.

**d. Hardware Evaluation**

The Contractor shall support the audit of NASA and NASA Contractor manufacturing of flight hardware, including in-process and end-item inspections for compliance with agency and project requirements. These evaluations shall be done in conjunction with the GSFC SMA Directorate.

**2.0 Laboratory Support**

The Contractor shall provide engineering and technician support for laboratory operations associated with the testing and analysis of organic, ceramic, composite and metallic materials typically used in space flight projects. Engineering and technician support may also be required in the areas of hardware cleaning, polymer mixing and applications, bonding operations, and lubricating of hardware. When required, the Contractor shall be responsible for maintaining laboratory facilities and equipment and maintaining equipment calibration in any laboratories where they are assigned to work. They may also be required to fill the position of Laboratory Manager in certain selected laboratories.

**a. Organic Materials**

The Contractor shall perform failure analysis, material investigations, process development, and analyses of organic materials.

***i. Organic Contamination Analysis***

The Contractor shall perform analysis of contaminants collected via cold fingers, witness mirrors or swab wipes.

*ii. Outgassing Tests*

The Contractor shall perform material outgassing tests in accordance with ASTM E-595-07, Standard Test Method for Total Mass Loss (TML) and Collected Volatile Condensable Materials (CVCM) from Outgassing in a Vacuum Environment. The Contractor shall support a computer database containing percent TML, percent CVCM, and percent Water Vapor Regained (WVR) for all materials tested.

*iii. Polymeric Application*

The Contractor shall perform polymeric applications for flight hardware. The Contractor should be capable of applying all of the Materials Engineering Branch documented procedures for polymers.

**b. Ceramic and Composite Materials Engineering**

The Contractor shall perform physical, chemical and mechanical testing of composite and ceramic materials as well as providing engineering support for failure analysis for these materials.

*i. Mechanical Testing*

The Contractor shall provide engineering support for mechanical testing of composite materials to verify lamina and laminate design allowables and to verify composite joint designs. Tests include tension, compression, shear, and fatigue at both room and cryogenic temperatures. The Contractor shall also provide support for the mechanical characterization of ceramic materials.

*ii. Physical Property Testing*

The Contractor shall provide engineering support for testing of ceramic and composite materials to measure or verify physical properties such as coefficient of thermal expansion, thermal conductivity, and moisture absorption.

**c. Metallurgical Engineering**

The Contractor shall perform material characterizations and failure analyses using procedures derived by the Contractor, various standards or, ISO standards.

*i. Metallurgical Analysis*

The Contractor shall prepare metallographic specimens and evaluate the metallurgical properties of metallic materials utilizing both optical and scanning electron beam microscopy. The Contractor shall also employ inorganic analysis techniques such as optical emission spectroscopy and energy dispersive spectroscopy to determine the material composition of metallic materials.

*ii. Printed Circuit Board Coupon Analysis*

The Contractor shall perform analysis of printed circuit board coupons for GSFC and GSFC Contractors in accordance with Materials Engineering Branch procedures and IPC standards IPC-6011, Generic Performance Specification for

Printed Boards and IPC-6012C, Qualification and Performance Specification for Rigid Printed Boards. The analysis shall be reported in accordance with project requirements for traceability, certification and schedule.

***iii. Nondestructive Evaluation***

The Contractor shall support nondestructive evaluation (NDE) operations including digital microfocus radiography, immersion and contact ultrasonics, thermography, dye penetrant and eddy current. These NDE inspections are performed on flight hardware and associated parts to detect flaws and failures to insure component reliability.

**d. Materials Identification and Certification**

The Contractor shall perform identification and certification of materials. This includes metallic, nonmetallic and composite materials.

**e. Life Testing**

The Contractor shall develop, design and provide equipment, write procedures and reports, conduct life tests on lamps, lubricated space mechanisms and other flight hardware items. The support should also include thermal cycling, performance testing, data collection and data analysis.

**f. Cryo-lab Support**

The Contractor shall provide support to the Materials Engineering Branch in stocking the tanks, maintenance and operation of equipment such as storage tanks, cryogenic chambers, supply piping and related safety equipment.

**g. Electrical Testing of Materials**

The Contractor shall provide support in testing electrical properties of materials such as ESD and resistivity.

**h. Reports and Publications**

The Contractor shall prepare reports of test and analysis results. Analysis shall be documented in a report format using photographs and diagrams as necessary and addressing objectives, techniques, results, conclusions and recommendations. Inspections and test results shall be documented according to project requirements for traceability and certification. Reports shall be suitable for distribution to center, agency and material discipline communities. When appropriate or required, the Contractor shall prepare GIDEP ALERTS for submission through the COTR and appropriate center channels.

**B. Structural Analysis and Loads Engineering**

Structural analysis support shall be required during conception, design and fabrication phases to provide loads development, finite element modeling and analysis, stress

analysis, dynamic analysis and other analytical support, including written reports and design review presentations; during integration and test phases to provide strength and dynamics testing support, including written test plans and reports and review presentations; and during post I&T phases to provide correlated finite element models and other pre-flight analytical support. The Contractor shall prepare presentations and present at various reviews such as Preliminary Design Reviews, Critical Design Reviews, Test Readiness Reviews, Pre-Environmental Reviews, Technical Peer Reviews, etc.

### **1.0 Finite Element Model Analysis**

The Contractor shall generate finite element models (FEM) of space flight, ground support equipment (GSE) and related structures with primary emphasis given to the use of the NASTRAN structural analysis program. The Contractor shall utilize FEM pre- and post-processor software, e.g., Patran or FEMAP, to aid in the development and modification, checkout and visualization of the NASTRAN models themselves as well as the FEM analysis results. FEM visualization processes shall include modern techniques for viewing mode shapes, and static and dynamic deformations, forces, stresses, and applied loads (including temperature) that aid in the understanding of the model and analysis results. Model checkout processes shall include checks that test the mathematical validity of NASTRAN models prior to their use in analyses. These validity checks can be found at <http://femci.gsfc.nasa.gov/ValidityChecks/>. In addition, capabilities shall exist for the checkout, modification, and visualization of models for use in analyses that require combining finite element models from several diverse sources into an overall system model. This latter capability shall address the possibility that some of the models may be delivered in codes other than NASTRAN and must be converted to NASTRAN prior to performing the overall systems analyses in NASTRAN.

While the majority of associated tasks will utilize only the linear analysis capability of NASTRAN, from time to time some analyses can only be addressed with non-linear techniques. Such tasks might include, but are not limited to generating finite element models to analyze structures with material or geometric non-linearities, contact problems, thin-film wrinkling, and micro electro-mechanical systems (MEMS). Capability to use the non-linear function of NASTRAN or other solvers shall be available.

Capability to use the optimization routines of NASTRAN, including topology shall also exist.

The Contractor shall provide support for modal testing of flight hardware in order to provide a test-correlated FEM to a project. The Contractor shall have the capability to perform cross-orthogonality checks comparing the FEM modes and mode shapes to those of the test hardware to ensure the FEM is adequately correlated.

### **2.0 ELV Flight Loads Analysis**

The Contractor shall perform coupled launch vehicle/payload flight loads analyses on task-specified payload configurations. Flight loads analyses include launch and ascent for expendable launch vehicles (ELV). These analyses may be directed toward derivation of

preliminary design limit loads or toward the derivation of payload-specific flight loads. Load parameters required may be acceleration, displacement, force, or stress.

The Contractor shall develop reduced dynamic models in Craig-Bampton format along with necessary output transformation matrices (OTM) for delivery to launch vehicle providers for performing coupled loads analysis (CLA). The model delivery shall include all necessary documentation to adequately describe the model and its intended use.

### **3.0 On-orbit Loads Analysis**

The Contractor shall perform coupled on-orbit loads analysis on task-specified payload configurations for ELV/payload and ISS/payload combinations. Load parameters required shall include acceleration, displacement, force and stress.

Perform on-orbit analysis for free-flying payloads including strength analysis for thermally induced and maneuvering loads, and the determination of dynamic environments due to on-board disturbances (jitter).

Loads from all ISS operations shall be included in on-orbit analyses for ISS/payload combinations. The Contractor shall determine loads resulting from grappling of payloads using remote manipulator systems (RMS), from berthing of payloads to carrier structures, from re-positioning of payloads using motorized devices (such as pivoting mechanisms, rotators, etc.), from firings of the maneuvering system and reaction control system while the payload is grappled or berthed, from extra-vehicular activities (EVA), from venting or jet-plumes, from tip-off at the time of deployment, and from any other loading events that may occur during on-orbit operations.

### **4.0 Stress Analysis**

The Contractor shall perform hardware-related stress and margin of safety analysis of spacecraft structures, electromechanical devices, and mechanisms using both classical "hand" stress analysis and computerized stress analysis techniques for all operational loading conditions. These analyses shall be directed toward sizing the required structural members to obtain the required strength and stiffness characteristics and toward demonstrating required stress margins of safety. This activity is a necessary prerequisite for fracture control implementation using safe life (fracture mechanics analysis) and fail-safe approaches.

The Contractor shall perform stress and margin of safety analysis of mechanical ground support equipment (MGSE) including, but not limited to, handling fixtures, dollies, and lift slings. The Contractor shall provide support for strength testing of flight prototype, ETU (Engineering Test Unit), and MGSE hardware.

### **5.0 Dynamic Analysis**

The Contractor shall perform frequency response, shock and vibroacoustic analyses to simulate spacecraft test and flight events. Analyses shall determine the acceleration,

velocity, displacement, and force response of the hardware due to random, transient, sinusoidal and acoustic vibration, and transportation and handling environments. Vibroacoustic analysis shall include capability to perform statistical energy analysis (SEA), FEM pressure load, boundary element method (BEM) and hybrid acoustic analysis. The Contractor shall derive equivalent test specifications, including force-limited or otherwise notched levels, which properly simulate dynamic flight environments and envelope transportation and handling loads. The Contractor shall develop associated environmental test plans, support testing and prepare post-test reports.

The Contractor shall provide support for dynamic testing of flight, prototype, ETU, and MGSE hardware.

#### **6.0 Fracture Control**

The Contractor shall develop fracture control plans for task specified ELV payloads and implement approved fracture control procedures. The Contractor shall perform fracture mechanics analyses in accordance with GSFC standards to ensure that the maximum crack size which can exist in structural elements, as determined by non-destructive test procedures, shall not propagate to failure as a result of intended service usage. The Contractor shall perform fail safe and containment analyses where appropriate to satisfy fracture control requirements.

#### **7.0 Systems Analysis**

The Contractor shall perform the structural analysis portion of multi-disciplinary systems analysis including Structural/Thermal/Optical (STOP) analysis and jitter analysis. STOP analysis capabilities shall include the ability to map predicted temperature profiles to a finite element model and to provide optical performance data to optical engineers. Jitter analysis capabilities shall include both modeling of on-orbit and other appropriate dynamic disturbances as well as providing required output to the necessary disciplines, e.g., optics, attitude control systems (ACS), etc.

### **C. Mechanical Engineering**

Mechanical systems support shall be required for conception, analysis, design, fabrication, integration, testing, deployment, maintenance, and certification of mechanical and payload carrier systems, mechanisms, and related ground support and test equipment. The Contractor shall develop appropriate Interface Control Documents (ICD's), Specification Documents, Verification Test Plans, and Work Order Authorizations as required. The Contractor shall prepare presentations and present at various reviews such as: Preliminary Design Reviews, Critical Design Reviews, Technical Peer Reviews, etc.

#### **1.0 Mechanical Systems Development**

The Contractor shall provide mechanical design and engineering services, including consultation services, for the support of GSFC spacecraft and instruments being

developed both in and out-of-house. The Contractor shall provide engineering services and/or consultation on mechanical requirements definition, review and optimization. The Contractor shall provide engineering services and/or consultation and/or review of structural loads, conceptual designs, detailed designs, integration plans, performance test plans, environmental qualification test plans, mass budgets, static and dynamic analyses, including kinematic analysis for concurrence with GSFC defined standards and practices. The Contractor shall develop risk and cost reduction plans. The Contractor shall provide support at task specified flight project meetings and reviews, which may require travel both within and outside the United States of America. Engineering services, consultation and/or review findings are to be documented in technical memorandums. Trip reports shall be submitted to the ATR for all travel, and shall include a summary of activities, all assigned action items, and necessary schedule information.

## **2.0 Mechanical Design and Drawing Production**

The Contractor shall perform detailed mechanical design studies, and provide designs and drawings of spacecraft structures, flight support and carrier structures, instrument structures, electromechanical devices, Ground Support Equipment (GSE), and mechanisms. The Contractor shall produce configuration layouts and accommodation drawings and iterate these drawings, as necessary, to satisfy mission objectives and specific science requirements such as instrument fields-of-view, access and other packaging needs. The Contractor shall provide conceptual designs and drawings of spacecraft structures, balloon structures, flight support and carrier structures, instrument structures, GSE, and mechanisms (i.e. deployable booms, choppers, shutter mechanisms, aperture doors, etc.). The Contractor shall be capable of designing precision mechanical structures using both conventional metallic materials and advanced composite material systems, with detailed knowledge of composite laminate and sandwich design for dimensional stability. The Contractor shall produce layout and detail fabrication drawings of all hardware mentioned above in Computer Aided Design (CAD) format fully compatible, at a minimum, with current releases of the following CAD tools: I-DEAS/NX and Pro-Engineer. In some instances, the use of Auto-Cad and/or SolidWorks shall be required under a task order.

## **3.0 Mechanical Drawing Checking**

The Contractor shall provide detailed mechanical drawing checking in accordance with ASME Y14.5M-1994, Dimensioning and Tolerancing and 500-PG-8700.2.5C, GSFC Engineering Drawing Requirements Manual. Checking 'redlines', detailing necessary changes to make a drawing compliant with the above standard, shall be provided for each drawing or model checked. Alternative forms of documenting the necessary drawing corrections may be used if there is a benefit to the government, upon concurrence by the ATR.

## **D. Electro-Mechanical Engineering**

Electromechanical systems are comprised of mechanisms and their associated electronics, and typically require precision motion. This is accomplished utilizing electromagnetic or other means for actuation, and sensors for detecting velocity, position, or other physical parameters, along with a closed-loop or open-loop feedback controller. Design and analysis services shall be provided by the Contractor to perform concept trades, concept design, and detailed design of electromechanical systems and their components. Fabrication, assembly, and testing services, including life testing, shall be provided so that the capability exists to develop prototype, ETU, and flight electromechanical systems. Types of electromechanical systems requiring expertise include magnetic bearings, active/smart structures, vibration isolation, and large aperture, lightweight systems. Severe environments that electromechanical systems are subjected to include, but are not limited to acoustic, EMI/EMC, magnetic, cryogenic, vacuum, 0-g, and launch vibration. Special handling and clean-room environments are to be utilized for assembly of mechanisms as appropriate.

The Contractor shall provide analyses using CAD and simulation tools utilizing hardware and software compatible with those used by the Mechanical Systems Division. The Contractor shall have expertise to set-up and operate electronic design and test equipment compatible with equipment used by the Mechanical Systems Division, and other equipment typically found in flight hardware development electrical and mechanical labs.

Mechanical related electromechanical tasks have mostly been covered in the mechanical section of this document. Tasks in addition, but not limited to, include design, analysis, selection, implementation, and testing of bearings, flex-pivots, and flexures. This requires expertise in bearing tribology as well as aerospace materials.

## **1.0 Robotics**

Robotic systems are electromechanical systems that specifically are used for providing autonomous or remote manipulation. Robotic systems typically possess multiple joints such that multiple solutions exist for a manipulator to move from one location to another. For this reason, support services shall include analysis to solve statics and dynamics of serial and parallel kinematic systems, and controller software development to implement the appropriate solutions for those systems. Expertise shall be required in the area of Orbital Replacement Units (ORUs), other robotically serviceable assemblies, and robotic manipulators and end-effectors, as necessary, to provide engineering support services.

## **2.0 Micro Electromechanical Systems (MEMS)**

Micro Electromechanical Systems (MEMS) techniques shall be applied to those applications requiring micro-miniaturization of mechanisms, or sub-assemblies of conventional mechanisms. Expertise in analysis and implementation of MEMS is required. This includes, but is not limited to, FEM analysis of small scale structures, materials, fabrication techniques, packaging, photolithography, lithography electroforming and molding (LIGA in German), interfacing with macro-components, micro-actuators, focused ion-beam milling and welding, and coatings and tribology issues.

### **3.0 Systems Design and Analysis**

System level electromechanical tasks include, but are not limited to system identification and modeling, both linear and non-linear as appropriate using MATLAB/Simulink or a similar modeling software. These models are used as a tool for design optimization, design verification, etc. Expertise in SISO and MIMO controllers is required.

### **4.0 Electronics and Electromagnetics**

Electronics and electromagnetics related tasks shall include, but are not limited to, the design, analysis, fabrication, implementation and testing of power electronic circuits for the drive and commutation of motors; precision, low noise signal conditioning and interface mixed-signal electronics for sensors, optical encoders, and thermistors; digital and microprocessor based controllers for the implementation of command and telemetry functions, Field Programmable Gate Arrays (FPGA) for digital signal processing and control systems algorithm implementation, embedded software for microprocessor based systems to implement digital filtering and control algorithms in sampled data systems, perform worst case, failure mode and performance sensitivity analysis of electronic systems to verify the suitability of the design for the range of operational and survival temperatures and the cosmic radiation environments; analysis, design, and troubleshooting of grounding, shielding, Electromagnetic Interference/Electromagnetic Compatibility (EMI/EMC) problems; the layout, fabrication, and population of printed circuit boards (PCB's); design and fabrication of the interconnecting harness for electronic assemblies; and the determination of the electromagnetic fields and the electromagnetically generated forces in electrical machinery. Expertise to provide design, analysis, fabrication, selection, implementation, and testing of electrical machines, actuators, and sensors is required.

### **5.0 Optomechanics**

Optomechanics is the mechanical design of optical components or the mechanical mounting of optical components. Optomechanical tasks shall include, but are not limited to, the design, analysis, fabrication, implementation, and testing of: mirrors, mirror mounts, optical mounts, translation stages, rotary and kinematic stages, fiber optic mounts and fiber optic adapters. Expertise shall be required in design, analysis, optimization, material selection, implementation, and component and system testing.

## **E. Thermal Engineering**

The Contractor shall provide thermal engineering support during all phases of the project; modeling and analysis design, integration and test, launch site support, and mission operations. Integration and test support can include thermal hardware procurement and installation, MLI design and integration, coatings applications, and functional testing and checkout.

### **1.0 Thermal Design**

The Contractor shall conceive and develop thermal and cryogenic designs for spacecraft and instrument systems and balloon payloads. Determine thermal interfaces between instruments and their support structure. Develop plans and/or procedures for thermal analyses and verification testing. Review, evaluate, analyze, and report on thermal design, implementation and development.

### **2.0 Thermal Analyses**

The Contractor shall perform thermal analyses for spacecraft, instruments, and ISS, ELV, sounding rocket and balloon payloads. Develop analytical mathematical models, including thermal mathematical models and geometric mathematical models, representing conductive and radiative heat transfer both internal and external to the spacecraft and payload, and including convection effects for balloon payloads. The Contractor shall determine heat fluxes, temperature distributions, and temperature gradients for all specified spacecraft and payload components and locations for all flight and on-orbit conditions and launch and landing sites if required. Perform thermal analyses and design studies for cryogenically cooled instruments, subsystems, and components. The Contractor shall develop new thermal analysis software and improve existing software. Thermal analysis software utilization shall include Systems Improved Numerical Differencing Analyzer (SINDA), Thermal Radiation Analyzer System (TRASYS), Thermal Synthesizer Systems (TSS), Finite Element Modeling and Post-processing (FEMAP/TCON), Thermal Desktop, or Thermal Model Generator (TMG).

### **3.0 Thermal Device Design**

The Contractor shall provide design of thermal subsystem components including Multi-Layer Insulation (MLI) and thermal blankets of all types, heat pipes, Loop Heat Pipes (LHP), heaters, coatings, radiators, thermoelectric coolers, Phase Change Materials, and other thermal control systems and devices.

### **4.0 Cryogenic GSE**

The Contractor shall perform thermal analysis and design for cryogenic GSE, including dewar systems; dewar subsystems and components; and optical, opto-mechanical, electrical, and electro-mechanical GSE required to operate at cryogenic temperatures.

### **5.0 Thermal Laboratory Support**

For the thermal lab, the Contractor shall provide electrical, mechanical, and software engineering support, as well as mechanical and electrical technician support, for the fabrication and testing of thermal and contamination control devices for flight and ground systems. Facility maintenance, including thermal vacuum chambers and data processing system, is included.

### **6.0 Thermal Vacuum Test Support**

The Contractor shall provide support in the area of thermal vacuum testing and thermal balance testing for spacecraft and instrument systems and balloon payloads. Prepare or

review test plans, test procedures, and test reports. Perform pre-test temperature predictions and post-test thermal correlations.

## **F. Contamination and Thermal Coatings Engineering**

The Contractor shall provide Contamination and Thermal Coatings Engineering support for all phases of GSFC Missions (e.g. spacecraft and instruments) and Special Projects (e.g. IRADs) including Contamination and Thermal Coatings Engineering project management, concept definition and concept validation, contamination control planning, mission design, analysis, assembly, coatings application, coatings measurement and validation, integration and testing, extraterrestrial dust analyses, monitoring of hardware cleanliness, transport and storage of hardware, launch site support, prelaunch, launch, on-orbit, post-launch, and returned hardware evaluation. The Contractor shall develop presentation materials and present at various project and GSFC reviews and meetings. The Contractor shall provide written documentation of work plans, test plans, contamination control plans, analysis results, coatings applications and measurements processes and testing results, and other work/task activities. Contractor shall be available for travel to spacecraft/instrument/vendor locations and launch sites for meetings.

### **1.0 Contamination Engineering Project Support and Management**

The Contractor shall provide skilled, qualified Contamination Engineering Project Support and Management for missions, spacecraft, instruments, subsystems, ground support equipment, flight experiments, and other hardware requiring contamination involvement. The Contractor shall develop, establish, and manage the overall approach to Contamination Control, addressing all mission phases, based on the hardware sensitivities to contamination (optics, thermal control surfaces, mechanisms, power system, and other subsystems).

The Contractor shall develop, document, and implement contamination control plans, determine contamination control requirements, and develop appropriate monitoring plans and procedures to assess contamination control requirement compliance. This effort shall be performed in compliance with applicable mission SMA requirements. The Contractor shall provide Project Support and Contamination Engineering Management to monitor, review, evaluate, analyze, and report on overall contamination engineering implementation, progress, issues, and results. The Contractor shall support project meetings, Branch meetings, support and present at project reviews, support technical interchange meetings, technical and peer reviews, champion team meetings, working group meetings, failure and materials process review boards, the coatings committee, facility cleanliness surveys/evaluations, lessons learned, knowledge capture, and other project meetings.

### **2.0 Contamination Engineering Analysis**

The Contractor shall develop analytical transport models (molecular, thruster plume, and/or particulate) for spacecraft and instrument systems, and other space flight hardware

and surfaces. The Contractor shall perform analyses of expected environments and conditions for the hardware and surfaces, and determine contamination transport levels, predictions of accumulations on surfaces, and identify any issues or potential issues based on the results.

The Contractor shall provide analytical services to include planning, preparing, executing, and presenting spacecraft, instrument, or special project contamination analyses. The Contractor shall use NASA approved software, tools, and methodology to perform electrostatic return analysis, ambient and self-scattering return flux analysis, fluid venting and thruster plume impingement analysis, including effects on the spacecraft environment, computational fluid dynamics analysis in support of contamination transport analyses, steady state molecular transport analysis, ascent venting analysis, transient molecular transport analysis, molecular conductance analysis of seals, light baffles, and vent paths, lubrication loss under vacuum, particle transport analysis, molecular diffusion analysis through bulk materials or the ambient environment, and column density analysis of the effects on the environment surrounding the hardware in question. The Contractor shall perform these detailed environmental analyses of all phases of assembly, integration, test, transportation, pre-launch (i.e., payload processing facilities, pre-launch operations up through launch), launch, orbit insertion, on-orbit, descent, and landing (as required), planetary operations, and returned hardware evaluations.

The Contractor shall perform contamination effects analyses including optical throughput and scattering, thermal properties, electrical shorting and high voltage corona discharge, and mechanical and bonding effects using best available data and software such as thin film effects calculators. The Contractor shall establish surface contamination limits based on allowable optical and thermal performance degradation, and conduct tradeoff analyses, analyzing specifications and reviewing requirement, under a variety of conditions, based on mission concerns, and shall summarize results in a report and present results to the project, Branch, and at various other meetings. The Contractor shall establish particulate and gaseous contamination limits for ambient temperature and cryogenic fluid systems. The Contractor shall establish gaseous purge criteria to control water vapor, hydrocarbons, and particulate contamination, including gas purity, flow rate, and purge implementation procedures. The Contractor shall develop new, and/or improve existing contamination engineering analysis software for each of the mission phases. The Contractor shall perform tape lift sampling and analysis according to GSFC 546-WI-8072.1.56A, Contamination Control Procedure for Tape Lift Sampling of Surfaces and provide reports of all events in IEST-STD-CC1246D, Product Cleanliness Levels and Contamination Control Program, and percent area covered formats where requested, and provide additional particulate contamination analysis as needed.

The Contractor shall monitor and model outgassing tests of materials, flight systems and associated components for the systems and subsystem level vacuum tests. The Contractor shall establish Quartz Crystal Microbalance (QCM) criteria and placement for outgassing verification of hardware. The Contractor shall trend, analyze, assess the impact, and

prepare reports on contamination test and flight data, and returned flight hardware samples, including particle tracking via video or other methods, light scattering, particle fallout, cleanroom air quality, optical witness mirror measurements, molecular residue accumulation, outgassing and thermogravimetric data, residual gas analyzer data, and NVR chemical analyses.

Contractor shall perform Space Environmental Effects analyses when applicable to missions, including: Atomic Oxygen, ultra violet (UV) photopolymerization, charged particle, electrostatic return, plume impingement, venting analyses, and micrometeoroid/debris impingement.

The Contractor shall analyze trends in clean room facilities for airborne particles and molecular deposition, complete relevant analyses and predictions on the performance of ovens and space environmental test chambers, determine suitability of test equipment for specific mission criteria and develop requirements for contamination control ground support equipment and flight hardware/instruments. The Contractor shall document all results in analysis reports, prepare and present analysis summary charts, and be available for travel to spacecraft/instrument/vendor locations and launch sites for meetings.

### **3.0 Contamination Laboratory Support**

The Contractor shall provide skilled, qualified support for the operations, maintenance, performance of measurements and testing, documenting of procedures, and reporting of measurements/testing results, for a variety of GSFC Contamination and Coatings Laboratories. The Contractor shall be ready to procure necessary lab maintenance equipment, new lab equipment and measurement devices, and supplies, if required.

Labs to be operated and measurements to be performed/supported include the Molecular Kinetics (MOLEKIT) facility (testing in accordance with ASTM E1559-09, Standard Test Method for Contamination Outgassing Characteristics of Spacecraft Materials, or equivalent GSFC 546-WI-8072.1.82A, MOLEKIT2/3 Operating Procedures. Catalog and present data for model input parameters); Bidirectional Reflectance/Scattering Distribution Function (BRDF/BSDF) measurements (i.e. reflectance and transmittance) on optical and thermal control samples for project support (in accordance with GSFC 546-WI-8072.1.80A, Measurement OF BRDF); Image Analysis measurements on samples and witness plates according to GSFC 546-WI-8072.1.81A, Determination of Particulate Contamination Using Automated Microscope/Image Analyzer; the contamination laser degradation/laser effects set-up; microscopic examination of contaminants on surfaces; evaluation of molecular and particulate contamination in other specific situations as they arise (e.g. evaluation of contamination from garments or; assisting with the development of new contamination measurement techniques and new testing chamber set-ups; setup and operation of microscopes and airborne particle counters to certify cleanrooms and cleanbenches according to ISO 14644, Cleanrooms and Associated Controlled Environments.

Contractor shall provide support for flight monitors during all mission phases: design, fabrication, testing, integration, launch site support, on-orbit data review, and data reduction. Flight monitors will be project or IRAD specific and independently funded.

#### **4.0 Development and Use of Contamination Standards**

The Contractor shall provide analysis and support for the development and ongoing evaluations of GSFC, NASA, national and international contamination control standards. Contractor shall develop, procure and calibrate, and test new equipment for the purpose of developing new standards or monitoring flight projects contamination control levels throughout each mission phase.

If necessary, the Contractor shall support these activities off site at conferences and working groups at professional society meetings or Branch supported functions. Contractor shall write and present technical papers and/or posters documenting the development of new techniques and standards in contamination control and thermal coatings. The Contractor shall submit work through the NASA Technology Reporting (NTR) process which commences through the Branch (where appropriate). Contractor shall become and remain familiar with and use new standards as they are developed and become applicable and which supersede existing standards.

#### **5.0 Cleaning Support and Technology**

The Contractor shall provide skilled, qualified cleaning personnel and validated cleaning procedures to perform precision cleaning for GSE, flight hardware, cleanrooms, and test set-ups. Contractor shall investigate, develop, procure, calibrate, and test new cleaning techniques, for example laser cleaning, CO<sub>2</sub> cleaning, vapor degreasing, etc., and applications to enhance our ability to provide and validate cleanliness of flight hardware. Techniques developed shall focus on surfaces that can be physically contacted as well as surfaces that cannot allow physical contact. The Contractor shall procure cleaning materials as required and test for cleanliness validation and compatibility.

#### **6.0 Thermal Coatings Engineering Project Support and Management**

The Contractor shall perform Thermal Coatings Engineering Project Support, Management, and Characterization for Missions and Special Projects, including working with other subsystems and project representatives. The Contractor shall manage thermal coatings engineering for the project and work with the project/subsystem engineers in the selection of appropriate thermal coatings for the mission or special project, for each surface requiring a coating. Once the thermal coatings are selected, the Contractor shall establish a complete coatings application and testing characterization program for each piece of hardware coated. The Contractor shall document all coatings test plans, approaches, application processes, testing results, reports, measurements, and when required, prepare/present presentation materials. Contractor shall provide training on coatings engineering, application processes, and testing methods to support engineers and utilize existing work instructions from the GSFC Goddard Directives Management System (GDMS) repository for documents 546-WI-8072.1.57A through 79A. The Contractor shall analyze the results of thermal coatings test and measurement, extrapolate

aging and environmental effects, and prepare reports on the suitability of coatings for a particular application. Contractor shall be available for travel to spacecraft/instrument/vendor locations and launch sites for coatings meetings.

#### **7.0 Thermal Coatings Characterization Measurements**

The Contractor shall perform flight qualification and space environment testing of coatings along with thermal radiative property measurements, thickness measurements, and coating adherence testing. The Contractor shall develop, operate, and maintain GSFC unique facilities to characterize, and qualify coatings for use on spacecraft, subsystem, and instrument surfaces. Contractor shall provide coatings support for molecular adsorber paint and proven flight adsorbers, and shall assist in the development of new coatings, application on new substrates, and new verification methods. The Contractor shall perform testing to characterize thermal control surfaces and assess degradation from environmental effects due to UV radiation, thermal cycling, charged particles, solar wind, electrostatic discharge, contamination, and humidity; develop and maintain a database of thermal property test data; and coordinate extended shelf life testing of paints. When appropriate, the Contractor shall develop and maintain GSFC, NASA, national, and international standards for the application and testing of space environmental coatings.

#### **8.0 Thermal Coatings Application**

The Contractor shall provide skilled, qualified personnel to apply thermal coatings to spacecraft, instruments, subsystems, surfaces, and special projects, in support of thermal control and contamination requirements. The Contractor shall be ready to procure flight qualified coatings, paints, supplies, coatings lab equipment and maintenance items. The Contractor shall develop and document methods of surface preparation and application for sprayed thermal control coatings (silicate, silicone, urethane based, and other coatings) and thermal control films (silver teflon, aluminized Kapton, Germanium Black Kapton, etc.). Contractor shall perform post application verification of coating to ensure coating meets specifications for thickness, adherence, appearance, uniformity, etc. and shall develop, document, and implement techniques for the refurbishment and cleaning of coatings to remove particulate and molecular contamination, and shall perform coatings repairs and 'touch-up' at GSFC, vendor, and launch site locations, as required. Contractor shall work to create new application and verification techniques as new substrates, shapes, and coatings are developed.

#### **9.0 Thin Film Deposition**

The Contractor shall provide skilled, qualified personnel to support in the area of vacuum vapor deposition and sputter deposited thin films, such as the GSFC composite coating, dark mirror, astronaut anti-reflective coating, vapor deposited aluminum or gold, silver, and various multi-layer composite coatings. Contractor shall provide support to prepare surfaces, ensure vacuum vapor deposition equipment is functional, apply thin film coatings on space flight part or other surfaces, document processes, and verify that deposited film meets uniformity, appearance, adherence requirements.

## **10.0 Planetary Protection**

The Contractor shall provide support to projects in the development and implementation of planetary protection per [NASA NPD 8020.7 Rev G](#), Biological Contamination Control for Outbound and Inbound Planetary Spacecraft.

## **11.0 Laser Damage Facility**

The Contractor shall perform laboratory measurements and analysis of laser induced optical damage on materials and surfaces as a function of contaminant thickness and number of laser shots. Maintain operation of Branch laser damage facility under HEPA filtration conditions.

## **G. Manufacturing Engineering**

The Contractor shall provide flight (including protoflight), and non-flight (including prototype) hardware fabrication and assembly support for spacecraft primary structure, secondary structure, instrument structures, mechanical subassemblies, components, mechanisms, electronic assemblies, electromechanical devices, thermal control devices and subsystems, and thermal flight experiments. All fabrication and assembly support shall be in accordance with the workmanship requirements of NASA-STD-8739.1A, NASA-STD-8739.4, Crimping, Interconnecting Cables, Harnesses, And Wiring and NASA-STD-8739.5, Fiber Optic Terminations, Cable Assemblies, And Installation; printed board standards IPC-6011, IPC-6012, IPC-6013, IPC-6015, IPC-6016, and IPC-6018, as well as all subsequent updates to these documents.

The developer shall implement a workmanship program to assure that electronic packaging technologies, processes, and workmanship meet mission objectives for quality and reliability per the requirements of the following standards:

- GPR 8730.6, Electrostatic Discharge (ESD) Control
- GSFC-STD-6001, Ceramic Column Grid Array Design and Manufacturing Rules for Flight Hardware
- “NASA-GSFC Workmanship Requirements For Water Soluble Flux Assurance”, Rev A,  
[http://sma.gsfc.nasa.gov/workmanship/docs/Workmanship\\_Requirements\\_for\\_WSF\\_Assurance\\_11102010.doc](http://sma.gsfc.nasa.gov/workmanship/docs/Workmanship_Requirements_for_WSF_Assurance_11102010.doc)
- NASA-STD-8739.1 Workmanship Standard for Staking and Conformal Coating of Printed Wiring Boards and Electronic Assemblies
- NASA-STD-8739.4 Crimping, Interconnecting Cables, Harnesses, and Wiring
- NASA-STD-8739.5 Fiber Optic Terminations, Cable Assemblies, and Installation
- NASA-STD-8739.6, Implementation Requirements for NASA Workmanship Standards

- IPC-J-STD-001ES, Joint Industry Standard, Space Applications Electronic Hardware Addendum (except Chapter 10 of this standard and Chapter 10 of IPC-J-STD-001E)
- IPC-2221 Generic Standard on Printed Board Design (except paragraph 3.1.1)
- IPC-2222 Sectional Design Standard for Rigid Organic Printed Boards
- IPC-2223 Sectional Design Standard for Flexible Printed Boards
- IPC-2225 Sectional Design Standard for Organic Multichip Modules (MCM-L) and MCM-L Assemblies
- IPC A-600 Acceptability of Printed Boards (Class 3 requirements)
- IPC-6011 Generic Performance Specification for Printed Boards (Class 3 requirements; except paragraph 3.5)
- IPC-6012B Qualification and Performance Specification for Rigid Printed Boards (Class 3/A requirements)
- IPC-6013 Qualification and Performance Specification for Flexible Printed Boards (Class 3 requirements)
- IPC-6015 Qualification and Performance Specification for Organic Multichip Module (MCM-L) Mounting and Interconnecting Structures
- IPC-6018 Microwave End Product Board Inspection and Test (Class 3 requirements)

All fasteners used in assembling or installation shall conform to 541-PG-8072.1.2B, GSFC Fastener Integrity Requirements.

The Contractor shall also provide support to fabricate mechanical ground support equipment, special test and evaluation equipment (including electronic equipment) necessary to support the operation of all mechanical hardware. In situations where hardware fabrication is required in a quick reaction mode and the Contractor decides to perform the task under subcontract, the Contractor shall minimize both the subcontract implementation and fabrication phases of the task. Subcontractors used for fabrication and/or assembly shall be ISO 9001 or AS9100 compliant. Individuals who perform manufacturing of or inspections of printed circuit boards, printed wiring assemblies, or cable harnesses for acceptance for use in mission hardware shall be certified to the applicable workmanship or printed circuit board standard and all relevant GPRs and PGs.

Contractors who work in on-site manufacturing areas shall create procedures that represent the processes to be used to manufacture the hardware and shall ensure that WOA steps are fully traceable to those procedures. Contractors shall be trained to those procedures. Build records shall be established to record in-process and end-of-line quality data.

### **1.0 Thermal Devices and Materials**

The Contractor shall have the capability to install active thermal control devices (heaters, thermostats, thermocouples, thermistors, heat pipes, CPLs, etc.). The Contractor shall have the capability to install thermal coatings and other passive thermal materials and

devices on space flight hardware (paints, chemical films, platings, oxide coatings, both ambient temperature and cryogenic temperature blanketing applications, etc.).

## **2.0 Hardware Protective Coatings**

The Contractor shall provide protective or specific performance coatings such as iridite, anodize, electroless nickel plating, and gold plating. The Contractor shall provide preparatory etching for dye penetrant testing and bonding applications on various materials such as aluminum, Invar, and titanium. The Contractor shall be able to perform close tolerance masking of substrates, prior to plating services, such as anodize. The Contractor shall be able to prime and paint surfaces, parts and assemblies as required.

## **3.0 Composites**

The Contractor shall provide fabrication of composite structures, including but not limited to, flat laminates, honeycomb sandwich structures (composite and aluminum), tubes, and trusses. The Contractor shall also provide unique tooling for composites manufacturing of custom shapes, including dimensionally stable, low distortion tooling. The Contractor shall provide machining of composites, fixturing and facilities for bonding composite elements to form completed assemblies. The Contractor shall provide for the co-cure and post cure of inserts into substrates of varying composition, located to a high degree of positional accuracy.

## **4.0 Electronics Fabrication and Assembly**

### **a. Ground Support Equipment**

The Contractor shall design, build, test, and deliver ground support equipment to commercial standards and including applicable NASA standards as specified in the task orders. Where ground support equipment (GSE) interfaces with flight equipment an analysis shall be performed to assure the compatibility between the GSE equipment and the flight equipment. The Contractor shall design the GSE such that no single failure can result in damage to the flight unit. If specified in the task, this shall be shown formally in a FMEA performed in conjunction with the SMA Directorate.

All GSE interfaces that connect to flight equipment shall be electrically tested before connection to flight hardware. If a modification is made to a GSE which affects a flight interface, the interface shall be re-tested prior to reconnection to flight hardware. GSE connectors which interface with flight hardware shall be maintained as flight connectors.

Formal quality assurance procedures shall be limited to flight interface circuitry and cables which contact flight hardware. Formal quality assurance shall be limited to a final inspection only. The Contractor shall generate and accept without modification GSE drawings meeting commercial standards.

## **b. Harness**

The Contractor shall fabricate and test flight harnesses from either GFE drawings or drawings developed by the Contractor from GFE interface documentation such as connector definition drawings and Interface Control Drawings (ICDs). The Contractor shall develop mechanical mockups of the payload as required. Flight harnesses shall be fabricated by flight solder and crimp certified technicians using standard space flight harnessing techniques except where new and unique methods are required for particular payloads and are developed in concert with the task technical monitor. Potting shall be performed by appropriately certified technicians. Proper assembly procedures shall be followed for all connector types. For nonstandard electronic packaging interconnects, contractor shall produce evidence of manufacturability and reliability. All contractors that fabricate harnesses shall be certified to NASA STD 8739.4 and all relevant GSFC GPRs and PGs.

## **H. Integration and Test Engineering**

Integration and test services may need to be supported at various locations, including vendor sites, NASA Centers, and Military sites.

### **1.0 Integration**

The Contractor shall be required to assemble and integrate thermal, mechanical, electromechanical, and electronic flight systems and subsystems. This requires the design, fabrication, and operation of ground support equipment such as cryogenic dewars, command and telemetry simulators and computerized data acquisition systems.

### **2.0 Testing**

The Contractor shall be required to design test sequences, establish pass/fail criteria and write test plans and procedures to characterize or verify the performance of the system under test; based on the performance requirements and the specified operational environment. The Contractor shall choose the proper transducers, instrumentation and test equipment required for the test, conduct the test and subsequently, analyze the test data and prepare reports summarizing the test results. The Contractor shall provide test and instrumentation capabilities to support these activities. The Contractor shall be capable of operating Mechanical Systems Division compatible equipment such as, but not limited to, dynamic signal analyzers, spectrum analyzers, analog and digitizing oscilloscopes, multi-channel data acquisition hardware, tunable frequency discriminators, logic analyzers, voltage and current meters and strip chart recorders. Transducers typically used include accelerometers, force transducers, displacement sensors, thermistors, and gauss meters.

Typical characterization and verification tasks in the area of test shall include, but are not limited to, the measurement of bearing torque, residual momentum, modal surveys of structures and mechanisms, measurement of transfer functions and transient behavior of

thermal, structural, mechanical, electromechanical, and electronic components and systems. Tasks shall also consist of life testing of electromechanical assemblies and mechanisms; measurement of disturbance rejection and jitter performance; reduce and display test data, automate test sequences and data acquisition, implement signal processing algorithms to identify trends, extract modal parameters, calculate transfer functions and power spectral densities.

The Contractor shall test and qualify hardware and software. These tests shall be conducted in accordance with Government-approved procedures and shall include both functional and environmental tests. Functional tests shall be designed and performed to demonstrate compliance with the operating requirements of the system. Environmental tests shall be designed and performed using environmental conditions that meet the launch, safety, and operations requirements of the assigned task. The Contractor shall have the capability to perform the following types of testing.

- a. In-process testing during the fabrication process to demonstrate that the design meets the requirements specified.
  - i. X-ray, dye penetrant, and eddy current inspections, as well as other forms of nondestructive analysis
  - ii. Tests to develop/validate models for structural, mechanical, thermal, optical, power, and electronic components and assemblies
- b. Functional testing.
  - i. Verification of operational characteristics of components and equipment
  - ii. Testing at Government facilities
  - iii. Testing and documentation to verify accuracy, repeatability, and stability while operating under simulated flight conditions
- c. Flight qualification testing on units that have successfully completed functional tests and have been prepared for space flight. These tests may be conducted at any of the levels of assembly specified in this Statement of Work, including on the spacecraft. The qualification tests shall be carried out in a test environment specified by the task order. The Government may provide test facilities and/or test equipment to the Contractor, as specified in the task order. Flight qualification testing shall include the following.
  - i. Vibration/Shock
  - ii. Magnetic

- iii. Thermal vacuum
- iv. Thermal balance
- v. Static loads
- vi. Acoustics
- vii. Mass properties
- viii. Alignment
- ix. Electromagnetic interference (EMI)
- x. Electromagnetic compatibility (EMC)
- xi. Gravity effects
- xii. Life tests
- xiii. Modal survey
- xiv. Deployments
- xv. Mechanism Performance

### **3.0 De-Integration**

The Contractor shall be required to disassemble and de-integrate thermal, mechanical, electromechanical, and electronic flight systems and subsystems.

## **FUNCTION 3 – Implementation Phase Services – Instrument Systems**

### **A. Optical Engineering**

#### **1.0 Optical Instrument Development**

The Contractor shall work independently and with teams consisting of other contractors, civil servants, and external collaborators to perform various assigned duties. The contractor shall provide technical support for the development of space flight optical instruments, airborne and ground-based optical instruments, and ground support equipment (GSE) for such instruments. They shall employ Quality Management System (QMS) procedural requirements when applicable. Depending on level of responsibility, they shall take lead roles with other team members to deliver optical components, sub-

systems, and systems, meeting technical and programmatic requirements and expectations. This may include developing and managing error budgets, schedules and plans.

The Contractor shall apply their knowledge of and experience with Optics, Optical Engineering, and/or supporting expertise to perform various functions in the development of optical instruments. Examples include optical design, modeling, and engineering, metrology, fabrication, alignment, integration, and testing. The contractor shall provide optical design, analysis and modeling services to perform concept trades, concept design, detailed design, and opto-mechanical component design studies. Knowledge of light-weighting techniques; thin film/coating design; baffle and associated stray light rejection design; conceptual and detailed optical mount design, opto-mechanical layout and packaging; fabrication and alignment sensitivity analysis and tolerancing, optical system error budgeting; and development of component specifications for engineering drawings is required. Contractor experience with optical design and analysis software, which is compatible with Code V, ZEMAX, or equivalent software is required. The contractor shall provide optical research and development involving prototype laboratory optical hardware, new optical algorithms for use in software codes, and novel optical design solutions and analysis techniques. Experience with the design, analysis, fabrication, alignment, and test of cryogenic infrared and vacuum ultraviolet optical instrumentation is recommended.

Related expertise that may be employed includes other fields of Engineering, data analysis, Mathematics, and Physics. The contractor shall communicate effectively and perform assigned ancillary responsibilities related to instrument development

## **2.0 Optical Analysis**

The Contractor shall provide optical, opto-mechanical, electro-optical and RF analysis support at the conceptual, preliminary, and detailed stages of components, subsystems, instruments and spacecraft. This support shall include the following topics: active and adaptive optics; geometrical and physical optics; deformable optics; diffraction; Gaussian beam propagation and interferometric modeling (Fourier optics) with experience in the use of the GLAD, ASAP, FRED, or equivalent software; stray light/energy analysis requiring experience with ASAP, TracePro, or FRED software and understanding of stray light fundamentals; component tolerancing and tolerancing sensitivity; radiometry (receivers, detectors and detector arrays); image quality (geometrical and diffraction); throughput; polarization; alignment and calibration; high precision optical metrology; and guided wave optics.

The contractor shall be capable of supporting all, including optical, analysis aspects of an interdisciplinary Structural-Thermal-Optical Performance (STOP) analysis task. This support includes conceiving physical transformations, implementing coordinate transformations, and developing the interface tools (macros, etc.) to accomplish this. The contractor shall support the subsystem, instrument and spacecraft analysis of system behavior and system error budgets and tolerances. The contractor shall also establish component tolerances based on allowable tolerance sensitivities, performance

degradation, and error budgets. The contractor shall also provide cost estimates of proposed optical systems, including fabrication and testing.

### **3.0 Optical Testing and Calibration**

The Contractor shall work independently and with teams consisting of other contractors and civil servants to perform various assigned duties. The Contractor shall provide technical support for testing, verifying, and calibrating optical components, subsystems, systems, and instruments. The Contractor shall develop techniques, procedures, and systems to perform these functions to acceptable uncertainties and requirements. The Contractor shall employ QMS procedural requirements when applicable. Depending on level of responsibility, they shall take lead roles with other team members to deliver interim and end products. This may include developing and managing schedules and plans.

The Contractor shall apply their knowledge of and experience with Optics, Optical Engineering, and/or supporting expertise to perform various optical testing, verification, and calibration. Examples include interferometry, wavefront sensing, optical modeling and analysis, mathematics, physics, and software development and use. The Contractor shall communicate effectively and perform assigned ancillary responsibilities related to testing and calibration.

### **4.0 Optical Metrology**

The Contractor shall work independently and with teams consisting of other contractors and civil servants to perform various assigned duties. The Contractor shall perform metrology, alignment, and related technical support for spacecraft, space flight, GSE, and other structures, components, systems, and scientific instruments. The Contractor shall have thorough knowledge of and follow applicable Quality Management System (QMS) directives based on GSFC's ISO 9001 certification as codified in and NASA/GSFC procedural requirements. The Contractor shall effectively employ data reduction and analysis software. Depending on level of responsibility, they shall take lead roles with other team members to perform metrology. This may include developing efficient technical approaches to meet requirements as well as schedules and plans.

The Contractor shall apply their knowledge of and experience with Optics, Optical Engineering, data analysis, error analysis, Mathematics, and Physics to perform metrology. The contractor shall communicate effectively and perform assigned ancillary responsibilities related to metrology.

### **5.0 Optical Proposal Development**

The Contractor shall work independently and with teams consisting of other contractors, civil servants, and external collaborators to perform various assigned duties. The Contractor shall provide technical support for the development of proposals for and studies of space flight, airborne and ground-based optical instruments and optical systems, and missions. Depending on level of responsibility, they shall take lead roles with other team members to develop portions of these proposals and studies. Examples

of this work include performing optical design, modeling, and analysis, scientific/engineering/systems requirements flow-down, optical systems engineering, performance trade studies, managing error budgets, and estimation of programmatic parameters.

The Contractor shall apply their knowledge of and experience with Optics, Optical Engineering, space flight heritage, related software use and development to achieve a competitive balance between scientific performance and optical system complexity. The Contractor shall communicate effectively and perform assigned ancillary responsibilities related to proposal development.

## **6.0 Optical Fabrication**

The Contractor shall work independently and with teams consisting of other contractors and civil servants to perform various assigned duties associated with the fabrication of space flight and non-space flight optical instrumentation and components. The Contractor shall provide technical support fabricating, coating, assembling, testing, and verifying optical elements, components, and systems. This includes the fabrication (includes cutting, grinding, polishing, tooling), assembly, and test of conventional and state-of-the-art non-typical precision optical components; cryogenic optical and opto-mechanical components; single point diamond turning fabrication; machining of non-optical glass components and hardware; in-process optical testing, characterization and integration including experience with metrology equipment; and opto-mechanical fabrication consulting to engineers, scientists, and project managers. These services may require the use of the GSFC Opto-mechanical Fabrication facility. The contractor might be expected to use any of the following types of optical equipment: WYKO and ZYGO phase measuring interferometer, Davidson interferometer, use of precision optical flats and radius test plates, diamond band and rotary saws, diamond surface grinder, cylindrical grinder, spherical generator, precision milling machine, metal lathe, bench top and standing drill press, lapping spindles, loose abrasives, diamond turning machine, and high precision optical polishing instrumentation. The Contractor shall employ QMS procedural requirements when applicable. Depending on the level of responsibility, they shall take lead roles with other team members to deliver interim and end products. This may include developing and managing schedules and plans.

The Contractor shall apply their knowledge of and experience with Optics, Optical Engineering, Optical Testing, precision fabrication methods and processes to perform the work. They shall develop new and improved methods, techniques, and processes. The contractor shall communicate effectively and perform assigned ancillary responsibilities related to optical fabrication.

## **7.0 Optical Integration, Alignment, and Test**

The contractor shall provide optical integration services necessary to install, align, and calibrate spacecraft or flight experiment instruments and components. These services may require integration operations in the GSFC Building 7/10/15/29 integration facilities, other NASA centers or contractor sites, and preflight operations at the launch site. The contractor shall provide optical alignment verification, testing, and calibration services on

flight, engineering model, and ground system optical instruments, breadboards and components; perform active alignment of systems; and perform pre- and post-environmental test distortion effects measurements. These services may require the use of the GSFC Optical Test Facilities and associated optical instrumentation and equipment which includes the Calibration, Integration and Alignment (CIA) facility, the Vertical and Horizontal Flow clean rooms, the Optical Calibration Lab (OCL) in Building 5, and additional experimental test areas in Building 7 and Building 5; use of other NASA centers or contractor sites. The Contractor might be expected to operate any of the following types of optical equipment: interferometers (i.e. ZYGO), angle generators, autocollimators, alignment telescopes, collimators and telescopes, optical levels, theodolites, optical plummets, clinometers, lasers, optical metrology systems (i.e. AIMS 11), photometers, detectors, radiometers, monochrometers, and spectrometers.

### **8.0 Optical Components and Materials**

The Contractor shall work independently and with teams consisting of other contractors and civil servants to perform various assigned duties. The contractor shall provide technical support procuring, testing, and verifying, and characterizing optical components and materials. They shall investigate multiple paths, both internal and external for developing and producing delivered products that meet technical requirements and which are cost effective. They shall employ QMS procedural requirements when applicable. Depending on level of responsibility, they shall take lead roles with other team members to deliver interim and end products. This may include developing and managing schedules and plans.

The Contractor shall apply their knowledge of and experience with Optics, Optical Engineering, and/or supporting expertise to perform the work. The contractor shall communicate effectively and perform assigned ancillary responsibilities related to the development of optical components and materials.

### **9.0 Wavefront Sensing and Control (WFSC)**

The Contractor shall provide support specializing in the area of image-based (non-interferometric) wavefront sensing and control. The Contractor should have a record (publications, project support) in the area of image-based wavefront sensing optimization and algorithm development, including phase retrieval, and a demonstrated track record in application of these wavefront-sensing techniques. The Contractor shall be experienced in the use of Code-V and Zemax optical ray-trace programs, and possess a demonstrated knowledge of optical “tolerancing” techniques. The Contractor shall have a demonstrated competency in the area of optical control techniques (system matrices, singular value inversion) including influence function characterization for both static and dynamic system correction, and shall have extensive demonstrated programming experience using Matlab. The Contractor shall also be able to lead and define optical wavefront minimization criterion for various optical systems and provide support and development of appropriate Fourier optics models. The Contractor shall have competency and experience in giving high-level, inter-agency, presentations to project management on wavefront sensing and control analysis. The Contractor shall have inter-

personal, communication skills, and the ability to work as a contributing member of teams.

## **10.0 Optical Technology Development**

The Contractor shall work independently and with teams consisting of other contractors, civil servants, and external collaborators to perform various assigned duties. The Contractor shall provide technical support for Optics, Optical Engineering, and related research, development, and new technologies. The Contractor shall team with civil servants and external partners to develop technology development proposals in accordance with the mission of the Optics Branch and the strategic priorities of their Division and Directorate, the Center, and Agency. Depending on level of responsibility, they shall take lead roles with other team members to perform this work.

The Contractor shall apply their knowledge of and experience with Optics, Optical Engineering, Physics, and related fields to perform this research and development, which may be targeted or directed by proposals, projects, and the Optics Branch. The Contractor shall communicate effectively and perform assigned ancillary responsibilities related to technology development.

## **11.0 Optical Engineering Advisory**

The Contractor shall work independently and with teams consisting of other contractors, civil servants, and external collaborators to perform various assigned duties. The Contractor shall provide technical and programmatic review and advice for scientific optical instruments, optical systems, spaceflight, airborne, and ground based missions. The Contractor shall utilize their knowledge and experience, both broad-based and/or specific to provide valuable and reliable insight as far as Optics, Optical Engineering, and related fields. Depending on level of responsibility, they shall take lead roles with other team members to organize and lead these reviews. The Contractor shall communicate effectively and perform assigned ancillary responsibilities related to their advisory responsibilities.

## **B. Cryogenic Engineering**

### **1.0 Cryogenic Systems Development – Low Temperature Engineering**

#### **a. Cryogenic Thermal Architecture Design**

The Contractor shall develop cryogenic designs for spacecraft and instrument systems and balloon payloads. The Contractor shall determine thermal interfaces between instruments and their support structure. The Contractor shall develop plans and/or procedures for cryogenic/thermal analyses and verification testing at low temperatures. Review, evaluate, analyze and report on the design, implementation and

development. The Contractor shall have expertise in the handling and application of liquid and vapor phase cryogenics such as Nitrogen and Helium.

**b. Analysis**

The Contractor shall perform thermal analyses for cryogenically cooled components, subsystems, and instruments, including balloon payloads. The Contractor shall develop analytical mathematical models, including geometric mathematical models, representing conductive and radiative heat transfer both internal and external to the payload. In the case of balloon payloads, pertinent convective effects will be included when necessary. The Contractor shall determine heat fluxes, temperature distributions, and temperature gradients for all specified payload components and locations for all flight and on-orbit conditions and launch and landing sites if required. The Contractor shall develop new analysis software and techniques as well as improve existing software. Preferred temperature analysis software will have compatibility with Systems Improved Numerical Differencing Analyzer (SINDA), Thermal Synthesizer Systems (TSS), Thermal Desktop or the Thermal Model Generator (TMG) software package.

**c. Component Design**

The Contractor shall provide design of cryogenic components for use in subsystem designs. This includes components such as MLI blankets of all types, ADR (Adiabatic Demagnetization Refrigeration) components, Thermal straps, Heaters, Heat Switches, Radiators and dewars.

**d. GSE**

The Contractor shall provide analysis and design for cryogenic GSE, including dewar systems; dewar subsystems and components; and optical, opto-mechanical, electrical and electromechanical GSE required to operate at cryogenic temperatures.

**e. Laboratory Support**

The Contractor shall provide design, assembly, instrumentation, insulation, data acquisition and processing and display, tests and report preparation on various systems. The Contractor shall support the preparation, data processing, and testing of flight and ground systems under thermal vacuum conditions. Facility repair includes the upgrades to laboratory equipment and maintenance of data processing systems. The Contractor shall also be adept at and able to perform set-up, operation, and maintenance of high vacuum systems.

**f. Product Development**

The Contractor shall provide electrical and/or mechanical technician support (e.g., wiring, magnetic coil wiring, etc.) and Laboratory based software engineering activities; for the fabrication, test and development of various cryogenic devices for both flight and ground systems. The Contractor shall evaluate GSFC and NASA contractor processing and quality facilities for required equipment, processes, personnel, training and capability for producing flight quality hardware.

**g. Hardware Evaluation**

In conjunction with the GSFC SMA Directorate, the Contractor shall support the audit of NASA and NASA contractor manufacturing of flight hardware, including in-process and end item inspections for compliance with agency and project requirements.

**h. Thermal Vacuum Test Support**

The Contractor shall provide support in the area of thermal vacuum testing and thermal balance testing for spacecraft and instrument systems, as well as balloon systems at cryogenic temperatures. The Contractor shall prepare and/or review test plans, test procedures, and test reports. Perform pre-test temperature predictions and post-test correlations. The Contractor shall provide support and direction with regards to the definition and development of GSE.

**2.0 Cryogenic Materials**

The Contractor shall provide cryogenic materials engineering support in the two areas of Materials Assurance Engineering and Cryogenic Materials Laboratory Support.

**a. Cryogenic Materials Analysis**

The Contractor shall provide cryogenic materials engineering support for the development and implementation of materials assurance programs for GSFC managed flight projects. Contractor cryogenics materials engineers shall assist GSFC project engineers with the selection and application of cryogenic materials and processes, plan and supervise investigations or evaluations, provide general cryogenics materials program management and assess the flight worthiness of all cryo-materials usage. This includes providing cryogenic engineering expertise to projects and designers in the form of consultation, guidance and review. This support will address reliability, product assurance, and quality assurance.

**b. Cryogenic Material Usage Lists**

The Contractor shall review and recommend flight usage for cryogenic material lists for GSFC managed flight projects in accordance with project requirements. The review process shall identify cryo-materials and their usage as standard or nonstandard and as compliant or noncompliant. Materials Usage Agreements shall be reviewed and approved or disapproved. The maintenance and distribution of material lists shall address requirements such as revision tracking and approval status.

**c. Laboratory Support**

The Contractor shall provide engineering support for laboratory operations associated with the testing and analysis of cryogenic materials and systems typically used in space flight projects. The Contractor shall be responsible for maintaining laboratory facilities and equipment and maintaining equipment calibration in any laboratories where they are assigned the position of Laboratory Manager.

### **3.0 Product Fabrication Services – Machining and Welding**

The Contractor shall provide machining and welding support in support of the development of cryogenic system related hardware for spacecraft, suborbital payloads, instruments, subsystems, and components. In addition to the traditional machines (drill presses, lathes, etc) Electrical Discharge Machining (EDM capability) is required. The contractor will also support a variety of mechanical assembly tasks.

## **FUNCTION 4 – Implementation Phase Services - Related Discipline Engineering**

### **A. Project Management**

The Contractor shall provide management services, including establishment of a management organization that ensures that all assigned task objectives are accomplished within specified schedule and cost constraints. Management shall provide frequent and timely status to the Government via cost, schedule, progress and other reports during all phases of work.

### **B. Mission Systems Engineering**

The Contractor shall provide systems engineering support for project development, reporting progress, and conformance to appropriate practices and specifications according to GPR 7123.1A, Systems Engineering. This shall include systems engineering specific tasks. The Contractor shall perform key mission and spacecraft-level systems engineering functions that include, but are not limited to operations concept development and support; architecture and design development; requirements analysis, identification, and management; validation and verification; interfaces and ICDs; mission environments; technical resource budget tracking; risk analysis, reduction and management; systems milestone review candidates; configuration management and documentation; and development of systems engineering management plan.

### **C. Instrument Systems Engineering**

The Contractor shall provide instrument systems engineering support for project development, reporting progress and conformance to appropriate practices and specifications according to GPR 7123.1A, Systems Engineering. The Contractor shall perform key Instrument systems engineering functions that include, but are not limited to instrument data processing development and support; instrument architecture and design development; requirements analysis, identification and management; validation and verification; interfaces and ICDs; mission environments; technical resource budget tracking; risk analysis, reduction and management; system milestone reviews; configuration management and documentation; and systems engineering management plans.

#### **D. Detector Engineering Services**

The Contractor shall provide design services that include performance of detailed design (leading to Preliminary and Critical Design Reviews) of the subsystems, components and assemblies that comprise the instrument/spacecraft/platform. This effort includes hardware and software (flight and ground) as well as ground support equipment (electrical, thermal, contamination, mechanical, and cryogenic). Documentation, including technical reports, drawings, schematics, block diagrams, layouts, parts and materials list, and equipment lists, shall be provided. The Contractor shall provide engineering services for state-of-the-art detection systems requiring low noise levels and calibrations traceable to physical standards including the design, development, test, and analysis of the systems.

#### **E. Flight Dynamics Engineering**

The Contractor shall provide Guidance, Navigation and Control (GN&C) engineering support for all phases of project development, monitoring and reporting progress and conformance to appropriate practices and specifications. This shall include performing Flight Dynamics engineering for attitude and trajectory control, vehicle guidance, space and launch vehicle dynamics, mission planning, space vehicle autonomous control, and flight dynamics.

#### **F. Power Systems Engineering**

The Contractor shall provide design services (leading to Preliminary and Critical Design Reviews) that include, but are not limited to, performance of detailed design of the subsystems and components, and assemblies that comprise the instrument, spacecraft and/or platform. This effort includes hardware and software (flight and ground) as well as ground support equipment. Documentation, including technical reports, drawings, schematics, block diagrams, layouts, parts and materials list, and equipment lists, shall be provided. The Contractor shall provide support of design, development, and analysis of power systems, non-flight ETUs, and qualified solar arrays and batteries. The Contractor shall also provide support of formal design reviews.

#### **G. Propulsion Systems Engineering**

The Contractor shall provide GN&C engineering support for all phases of project development, monitoring and reporting progress and conformance to appropriate practices and specifications. Such support shall include, but is not limited to, development of spacecraft propulsion subsystems, advanced propulsion technology development, fluid systems, power and electric propulsion systems development, propulsion chemical analyses, support of advanced mission studies, support of design reviews, and fabrication, assembly, and I&T of propulsion systems.

## **H. Guidance, Navigation and Control Engineering**

The Contractor shall provide design services (leading to Preliminary and Critical Design Reviews) that include, but are not limited to, performance of detailed design of the subsystems (including support of formal reviews), components and assemblies that comprise the instrument/spacecraft/platform. This effort includes hardware and software (flight and ground) as well as ground support equipment. Documentation, including technical reports, drawings, schematics, block diagrams, layouts, parts and materials list, and equipment lists, shall be provided. Such support shall include design, development and test of advanced GN&C sensors and actuators and ground support equipment; hardware and software validation; design, development and test of hybrid dynamic simulator and systems design; GN&C systems technology development; and maintenance of mass, power, and pointing budgets, and operations planning. The Contractor shall provide GN&C engineering support for all phases of project development, monitoring and reporting progress and conformance to appropriate practices and specifications, that includes, but is not limited to: subsystem engineering; conceptual design, modeling and simulation; science and instrument interface engineering; spacecraft re-entry systems engineering; re-entry debris analysis, modeling and simulation; advanced systems technology development; balloon, UAV and sounding rocket engineering; formation flying test bed (FFTB) design and development; and technical consultation and support (proposals, peer, design, and anomaly reviews).

## **I. Communications, Command and Data Handling Engineering**

The Contractor shall provide support for the development of the communications and data handling system during the implementation phase, taking into account the results of formulation phase studies. Support shall include detailed design of circuit cards and enclosures; fabrication and test of circuit cards (including bench checkout equipment), engineering test boxes, and flight boxes; hardware/software integration of test and flight software; performance of both box and subsystem level tests including environmental qualification tests; integration of the C&DH system into the spacecraft; spacecraft level tests; field support in preparation for launch; and launch on-orbit operations. C&DH testing shall at times require the generation of new test procedures or modification of existing test procedures. Much C&DH testing shall require the use of the STOL computer testing control language. All testing shall require documentation of the procedures used, all actions taken, and the test results. The Contractor shall provide support RF design and analysis. The Contractor shall coordinate the analysis and designs for handling Doppler-ranging and antenna-pointing with ACS engineering. The Contractor shall ensure that RF architectures can maintain digital radio link margins and pointing requirements for the entire useful life of the spacecraft. The Contractor shall ensure that spacecraft RF receivers and demodulators are protected against desensitization from powerful terrestrial

or space borne emitters. The Contractor shall ensure that the C&DH subsystem reliably (as prescribed in the task and/or system/mission requirements) processes and provides all onboard users with the appropriate time code and/or clock signals for (a)synchronous operation over the full useful life of the spacecraft. The contractor shall support the design and/or specification of a spacecraft data recorder. The contractor shall support the design and/or specification of a spacecraft communications data processor. The contractor shall support the design and/or specification of a spacecraft transmitter or transponder capable of transmitting telemetry data. The contractor shall support/provide the design of millimeter wave systems.

## **J. Software Engineering**

The Contractor shall provide software design services, including the design, development, analysis, coding, and testing of: real-time flight systems control, monitoring and data processing, command and data handling, attitude determination and control, power subsystem control and monitoring, science data collection, processing, storage, and downlink; flight system simulation and modeling software; ground and flight system software; science support software data systems; instrument software; and information management-based system and associated application software.

## **K. Electrical and Electronics Engineering**

The Contractor shall provide engineering and design services (leading to Preliminary and Critical Design Reviews) that include performance of detailed design of the subsystems, components and assemblies that comprise the instrument, spacecraft and/or platform. This effort includes hardware and software (flight and ground) as well as ground support equipment. Documentation, including technical reports, drawings, schematics, block diagrams, layouts, parts and materials list, and equipment lists, shall be provided. The Contractor shall provide electrical/electronic design services , including the design, development and analysis of: flight electronic systems; command and data handling systems; flight and ground data systems; low noise electronics; digital and microprocessor based designs; control systems; high and low voltage systems; power supplies with programmable voltage and current outputs; electromagnetic field analysis; electromagnetic compatibility and interference (EMC/EMI); test circuitry and equipment; ground support equipment, high speed and communication electronics; microcontroller based systems and embedded systems; flight and test harnesses; breakout boxes; simulators; FPGA-based reconfigurable computing systems; ASIC devices (analog and mixe-signal); and lab view based systems.

## **L. Launch and Post-Launch Operations Support and Engineering**

The Contractor shall supply launch and post-launch mission systems level, systems level, software, and ground systems support services for ELV, sounding rocket, balloon, and aircraft-based missions, including launch site preparation; launch operations; mission operations support; landing and de-integration; refurbishment of recovered systems; data reduction; and documentation, such as, post-flight summary reports and analysis of the system performance during flight.

## **M. Mission Assurance Engineering**

The Contractor's ISO 9001 quality management system (or certified quality management system) and risk management processes shall extend to all flight hardware/software and critical GSE fabricated/provided under this contract. The Contract shall also provide assistance for institutional fabrication efforts; provide reports on manufacturing support activities, which shall comply with NASA and GSFC processes and procedures guidelines; support integration and test activities, including, but not limited to, performing inspections, ensure compliance with approved test and calibration procedures, and ensure that anomalies and non-conformances are documented; comply with all ESD requirements; generate reports which document test results; support audit activities of flight products; ensure deliverables comply with product assurance requirements and implementation plans; ensure that all electronics packages and processes are compliant with NASA workmanship standards; review procurement requests for flight hardware for inclusion of assurance provisions; and ensure that the accuracy of all on-site and off-site measurement and test equipment (MTE) is controlled per the provisions of NPD 8730.1 Rev. C, Metrology and Calibration, AS9100 Rev. C, Quality Management Systems - Requirements for Aviation, Space and Defense Organizations, and GPR 8730.1K, Calibration and Metrology, including the repair, calibration and certification of MTE.

## **N. System Safety Engineering**

For all levels of flight hardware and software provided by the Contractor and specified by this Statement of Work, the Contractor shall establish and maintain a mission assurance program commensurate with mission requirements as specified by the task. For ELV missions at ETR or WTR, the system safety program shall meet the requirements of NASA-STD 8719.24, NASA Expendable Launch Vehicle Payload Safety Requirements. The Contractor shall establish and maintain practices, procedures, and processes that are ISO 9001 and AS9100 compliant. In conjunction with the GSFC SMA Directorate, the Contractor shall also establish safety plans and assess flight designs that are in concert with NASA safety standards, conduct test/validation programs for critical flight and ground systems software; perform hazard analysis, and prepare safety data packages.

## **O. Radiation Engineering**

The Contractor shall provide design services (leading to Preliminary and Critical Design Reviews) that include performance of detailed design of the subsystems, components and assemblies that comprise the instrument, spacecraft and/or platform. This effort includes hardware and software (flight and ground) as well as ground support equipment (electrical, thermal, contamination, mechanical, and cryogenic). Documentation, including technical reports, drawings, schematics, block diagrams, layouts, parts and materials list, and equipment lists, shall be provided. The Contractor shall also provide support for, but not limited to, determination of mission-specific system level impact of radiation test results and evaluations of mission radiation risk assessments, screening of parts list of radiation vulnerable devices, maintenance of radiation effect test data, development of interface software, operation and maintenance of radiation facilities and equipment, and analysis of space environment modeling.

## **P. Ground System Engineering**

The Contractor shall provide data systems management services, including ensuring all software (ground/flight) packages and interface problems are resolved; developing, reviewing, and analyzing software requirements; recommending solutions for software designs; preparing and analyzing documentation related to studies, design interfaces and procedural handbooks; developing data processing system schedules; validation of ground and onboard computer system simulators/emulators; support mechanical and electrical interface tests during various stages of development.

## **Q. Parts and Materials Engineering**

The Contractor shall keep a record of all Government furnished parts and equipment (GFE). The Contractor shall ensure that all parts procured conform to the parts program set forth in the applicable GSFC Mission Assurance Requirement. Flight piece parts and equipment shall be kept in bonded storage. All GFE parts and equipment that are intended for flight shall have any associated documentation that is furnished by the Government evaluated by the Contractor for suitability for use under the applicable task quality assurance requirements; any discrepancies shall be noted and identified to the Government.

## **R. ELV and ISS Mission Engineering Management**

The Contractor shall provide support in the development and maintenance of payload requirements and in the implementation of these requirements by ELV and ISS Programs,

including: all phases of mission planning, such as, payload requirement definition and implementation; and analytical support to ensure requirements are met. The Contractor shall also support team meetings, teleconferences, I&T meetings, and all reviews, which could include, flight operations, payload integration, and pre-ship, as well as providing support for payload safety analyses. The Contractor shall also write ISS payload interface and integration documentation related to payload system analysis, design, and environmental testing, launch, and in-flight operations.

## **T. Configuration Management Services**

The Contractor shall provide overall management and oversight of the Configuration Management (CM), Documentation Management (DM), and Quality Control Management (QCM) disciplines throughout the life cycle of flight hardware and software provided within the scope of this Statement of Work. Each discipline shall require the development, establishment, and implementation of procedures and processes and establishment of mechanisms and tools for consistency.

The Contractor shall support the planning, identification of processes, and leading GSFC Project efforts in these disciplines. This support shall also include the necessary planning and associated process development to assist the GSFC Project in meeting conformance requirements to NASA procedures and guidelines as well as the ISO standards

## **U. Hardware Refurbishment and Re-Use**

The Contractor shall provide support for refurbishment of previously flown flight hardware, in both the mechanical and electrical areas. Redesign and upgrades to the flight hardware shall be provided as required. Mechanical support shall consist of determination and tracking of maximum usable life, structural recertification as required by the particular project, inspection for defects that would prevent re-flight, and testing of mechanisms. Electrical support shall consist of reprogramming as required and functional testing at the box or subsystem level.

## **V. Training**

The Contractor shall provide training support of astronauts, the payload team (including the payload customer and staff), and the mission ground support team for space flight mission operations. Areas of training include flight documentation, mission re-planning and execution, flight rules, flight plan, payload operations, control center operations, spacecraft to ground telecommunications, spacecraft attitude, and operational constraints.

In that mission simulations contribute to training of mission support staff, the Contractor shall be responsible for planning and coordinating intra- and inter-center mission simulations prior to launch of the spacecraft and payload.

### **W. CAD/CAE Facility Support Services**

Provide operational and technical support for the Code 540 CAD/CAE facilities and systems as needed. The key software tools in use are: NASTRAN, SDRC I-DEAS, Siemens' FEMAP and PTC's Pro-Engineer running on a mixed network of Unix and latest Windows operating systems. The Contractor shall also provide any needed training for any CAD/CAE software tools employed by the Mechanical Systems Division.

### **X. Hardware Storage**

The Contractor shall provide a temperature/humidity controlled area maintained between 60° F and 80° F with relative humidity maintained between 30% and 50%, and of at least 8,000 square feet where Government and Contractor property including flight mechanical structures shall be stored. This facility shall be within the Washington Metropolitan area.

The Contractor shall provide a temperature/humidity controlled area, with the same limits as the above property storage area, as a bonded storage facility of at least 700 square feet where flight electronics equipment and parts are stored. The Contractor shall organize this area by tasks. Contractor task leaders shall have full authority and ability to remove/pull items associated with the corresponding task. Emergency procedures shall exist to allow access to bonded storage after normal working hours and on weekends.

## **FUNCTION 5 – Research and Technology Services**

The Contractor shall be able to perform the following list of research and technology development (R&TD) support services to support new NASA missions and applications, with emphasis on the services that have full descriptions below. R&TD support services under this contract shall include but not be limited to:

- a. Miniaturization and Micro-Electromechanical (MEMS) Devices
- b. Advanced Composite Structures and Joints Development
- c. Inflatable Structures
- d. Materials Development
- e. Magnetic Bearings
- f. Advanced Electro-mechanical Systems
- g. Light-weight Precision Deployable Structures
- h. Mechanical Analysis and Simulation Tools
- i. Robotics

### **A. Advanced Thermal Control Systems**

The Contractor will develop advanced thermal control technologies to support new NASA missions and applications. This might include capillary pumped loops, variable emittance thermal control surfaces, loop heat pipes, cryogenic heat pipes, heat pumps, alternative materials, and other such technologies. Support the development of thermal flight experiments.

### **B. Optics and Opto-Mechanical Systems**

The Contractor will develop advanced optical and opto-mechanical technology for components, subsystems, and systems for space-flight and GSE optical instrumentation to support new NASA missions and applications. Such technology might include novel materials for lightweight optical components, mounts, and support structures; state-of-the-art diffractive optics and characterization; novel thin film design, fabrication, and characterization processes, new optical design concepts and analysis techniques; state-of-the-art optical fabrication and test methods, etc.

### **C. Cryogenic and Fluid Systems**

The Contractor will develop advanced cryogenic and fluid systems to support new NASA missions and applications. Such systems might include structural and thermal interfaces to mechanical refrigerators, components for an advanced adiabatic demagnetization refrigerator, and cryogenic actuators.

#### **D. Advanced Coatings and Film Technology**

The Contractor will develop, procure and calibrate, and test new technology to apply, test, and maintain new or existing coatings and films. Provide offsite support for the use of these techniques. Write and present papers documenting the development and application of this new technology.

## **FUNCTION 6 – Support Services**

The Contractor shall provide support services covering all items within the scope of this SOW, as specified in task assignments. All work shall be performed in accordance with the latest versions of the applicable documents, specifications and standards under this SOW, and as further specified on individual task orders.

### **A. Documentation Services**

The Contractor shall provide documentation services for all levels of hardware and software within the scope of this Statement of Work, as specified in task assignments. Documents shall conform to applicable documents and specifications. These shall include, but are not limited to, pertinent NHBs, SMAP, and/or Program/Project-specific performance assurance guidelines, quality standards, GSFC standards, documents of other NASA Centers, Federal standards, military standards, and commercial standards.

The Contractor shall provide documentation services, including instrument conceptual designs, program plans, systems analyses, illustrations, technical and implementation plans, test plans, test procedures, test scripts, software documentation, and the full range of system hardware and software documentation. These shall also include up-to-date drawings, specifications, certifications, reports, interface control documents, and agreements.

#### **1.0 Document Services Specific Tasks**

The Contractor shall provide electronic media and document services, including the following.

- a. Technical writing
- b. Editing
- c. Drafting
- d. CAD/CAM
- e. Photographic
- f. Video
- g. Reproduction
- h. CD, DVD
- i. Posters and Displays

#### **2.0 Photo and Video Specific Tasks**

The Contractor shall use photos and video for maintenance, engineering, or as documentation to explain a problem. They shall become supplemental to assist in unit

repair or future development and maintenance. A scale shall be included to indicate relative dimensions in photographs and/or video, where appropriate.

## **B. Computer Technology Support Services**

The Contractor shall provide computer technology services, including the following.

### **1.0 Computer Support Specific Tasks**

- a. Engineering support to analyze data acquisition, processing, distribution, archival/storage, and measurement problems
- b. Data reduction to include statistical and thematic trends analyses
- c. Diagnostics assistance for instrument checkout between test consoles and test components
- d. Program services to utilize test instruments in aerospace system test and analysis, including GPIB-type operation and GUI based software systems
- e. General in-house computer software maintenance to include, but not be limited to, updating and debugging programs
- f. Design, coding, integration, test, documentation, and maintenance of special applications programs
- g. Updating of existing technical in-house computer databases
- h. Transfer of programs from one system to another and testing for functional operations and real time data transfer between dissimilar systems
- i. Debugging of general utility programs, such as graphic packages
- j. Assistance in analyzing and implementing solutions to computer hardware interface problems
- k. Assistance in network and operating system configurations, troubleshooting, installation, and maintenance
- l. Design and debug of test procedures

### **2.0 IT Systems Security and System Administrator Function**

- a. Each Contractor(s) System must have an associated System Security Plan (Contractor's, Center, AETD or Project Plan)
- b. Contractor's IT Security Plan will be reviewed annually
- c. Track Inventory of Data Systems Monthly (Systems entering and exiting NASA's perimeter boundary)
- d. All System must comply with NASA rules and regulations, including NPR 2810.1A, Security of Information Technology and NPD 2810.1D, NASA Information Security Policy, etc.

In addition to any other requirements of this contract, all individuals who perform tasks as a system administrator or have authority to perform tasks normally performed by system administrator shall be required to demonstrate knowledge appropriate to those tasks. This demonstration, referred to as the NASA System Administrator Security

Certification, is a NASA funded two-tier assessment to verify that system administrators are able to:

1. Demonstrate knowledge in system administration for the operating systems for which they have responsibility.
2. Demonstrate knowledge in the understanding and application of Network and Internet Security.

Certification is granted upon achieving a score above the certification level on both an Operating System test and the Network and Internet Security Test. The Certification earned under this process will be valid for three years. The criteria for these skills assessment has been established by the NASA Chief Information Officer. The objectives and procedures for this certification can be obtained by contacting the IT Security Awareness and Training Center.

A system administrator is one who provides IT services, network services, files storage, web services, etc. to someone else other than themselves and takes or assumes the responsibility for the security and administrative controls of that service or machine. A lead system administrator has responsibility for information technology security (ITS) for multiple computers or network devices represented within a system; ensuring all devices assigned to them are kept in a secure configuration (patched/mitigated); and ensuring that all other system administrators under their lead understand and perform ITS duties. An individual that has full access or arbitrative rights on a system or machine that is only servicing themselves does not constitute a "system administrator" since they are only providing or accepting responsibility for their system. An individual that is only servicing themselves is not required to obtain a System Administrator Certification.

## **C. Maintenance Services**

The Contractor shall provide maintenance support to ensure long term reliability through an integrated and efficient approach.

### **1.0 Preventive Maintenance**

The Contractor shall perform preventative maintenance on hardware and software within the scope of this Statement of Work as specified in task assignments.

### **2.0 Emergency Repair Services**

The Contractor shall provide expeditious emergency repair services for hardware and software within the scope of this Statement of Work, as specified in task assignments. The Contractor shall respond to the Government within four hours of notification to determine and implement a mutually agreeable course of action. In some cases, there shall be 24-hour coverage during flight hardware and software evaluation, verification, and test. This service shall comprise of repair, modification, or replacement of

components, codes, subassemblies, and assemblies. Documentation updates shall be required as a result of any change.

#### **D. Sustaining Engineering Services**

The Contractor shall provide sustaining engineering services for hardware and software within the scope of this Statement of Work, including the following:

- a. Modifications of hardware/firmware and software, including installation of elements for improved reliability and/or performance
- b. Modifications of wiring to improve circuit performance
- c. Non-flight fabrication, assembly, wiring, and testing of printed circuit assemblies where necessary to update old circuitry or improve reliability
- d. Engineering, non-flight fabrication, testing of assemblies or sub-assemblies to replace outdated circuitry to eliminate component or circuit failures
- e. Engineering, non-flight fabrication, assembly, and testing of engineering circuits to correct problems encountered during testing
- f. Modifications of mechanical assemblies, structures, and mechanisms to correct or improve the design
- g. Update of drawings, manuals, and technical data to reflect current status at the time of modifications
- h. Firmware and software modifications in response to approved changes, including problem fixes

#### **E. Education Services**

The Contractor shall provide education services, including the following:

- a. Supporting the GSFC engineering education and development programs

Supporting educational outreach programs with universities and NASA headquarters

- b. Supporting GSFC division or branch-level educational programs and training

## **F. Standards and Process**

The Contractor shall provide support for engineering standards work and engineering process work, including the following:

- a. International Standard Organization (ISO) documentation and process generation
- b. Engineering standards documentation and review
- c. Engineering process documentation
- d. Activities in support of engineering process improvement

#### **IV. APPLICABLE DOCUMENTS AND SPECIFICATIONS**

The Contractor shall adhere to all applicable portions of the following documents and/or specifications in the performance of this contract. Documents and specifications include, but are not limited to, those shown below. Additional applicable documents shall be specified on a task order basis. The latest updated version shall apply:

General:

NPR 7120.5E, NASA Program and Project Management Processes and Requirements  
GPR 7123.1A, Systems Engineering  
NPR 8705.4, Risk Classification for NASA Payloads  
GPR 8070.4B, Administration and Application of Goddard Open-Learning Design  
GPR 8700.6B Engineering Peer Reviews  
GSFC-STD-1000E, Goddard Space Flight Center (GOLD) Rules for the Design, Development, Verification, and Operation of Flight Systems  
NASA/SP-2007-6105 Rev 1, NASA Systems Engineering Handbook  
[NASA NPD 8020.7 Rev G](#), Biological Contamination Control for Outbound and Inbound Planetary Spacecraft  
NPD 8730.1 Rev. C, Metrology and Calibration  
GPR 8730.1K, Calibration and Metrology  
AS9100 Rev. C, Quality Management Systems - Requirements for Aviation, Space and Defense Organizations  
NPR 2810.1A, Security of Information Technology  
NPD 2810.1D, NASA Information Security Policy  
320-MAR-1001D Standard Mission Assurance Requirements (MAR)

Launch Vehicles:

NASA-STD 8719.24, NASA Expendable Launch Vehicle Payload Safety Requirements”  
NPR 8715.7, “Expendable Launch Vehicle Payload Safety Program

Conformal Coating and Staking:

NASA-STD-8739.1A, Workmanship Standard for Polymeric Application on Electronic Assemblies

Soldering – Ground Systems:

Association Connecting Electronics Industries (IPC) J-STD-001E, Requirements for Soldered Electrical and Electronic Assemblies  
IPC-J-STD-001ES, Space Applications Electronic Hardware Addendum to IPC-J-STD-001E Requirements for Soldered Electrical and Electronic Subassemblies (except Chapter 10)

Electronic Assemblies – Ground Systems:

IPC-A-610E, Acceptability of Electronic Assemblies

Crimping, Wiring, and Harnessing:

NASA-STD-8739.4, Crimping, Interconnecting Cables, Harnesses, and Wiring

Fiber Optics:

NASA-STD-8739.5, Fiber Optic Terminations, Cable Assemblies, and Installation

Electro-Static Discharge (ESD) Control:

ANSI/ESD S20.20-2007 Protection of Electrical and Electronic Parts, Assemblies and Equipment (Excluding Electrically Initiated Explosive Devices)

GPR 8730.6A, Electrostatic Discharge (ESD) Control

Printed Wiring Board (PWB) Design:

500-PG-8700.2.2C, Electronics Design and Development

500-PG-8700.2.4E, Mechanical Design and Development

500-PG-8700.2.5C, Engineering Drawing Requirements Manual

IPC-2221, Generic Standard on Printed Board Design

IPC-2222, Sectional Design Standard for Rigid Organic Printed Boards

IPC-2223, Sectional Design Standard for Flexible Printed Boards

IPC-2225 Sectional Design Standard for Organic Multichip Modules (MCM-L) and MCM-L Assemblies

GSFC-STD-6001, Ceramic Column Grid Array Design and Manufacturing Rules for Flight Hardware

NASA-GSFC Workmanship Requirements For Water Soluble Flux Assurance, Rev A,

[http://sma.gsfc.nasa.gov/workmanship/docs/Workmanship\\_Requirements\\_for\\_WSF\\_Assurance\\_11102010.doc](http://sma.gsfc.nasa.gov/workmanship/docs/Workmanship_Requirements_for_WSF_Assurance_11102010.doc)

PWB Manufacture:

GSFC-EEE-INST-002, Instructions for EEE Parts Selection, Screening, Qualification, and Derating - Incorporated Addendum 1: April 2008

IPC A-600, Acceptability of Printed Boards (Class 3)

IPC-6011, Generic Performance Specification for Printed Boards (Class 3)

IPC-6012B, Qualification and Performance Specification for Rigid Printed Boards Flight Applications – Supplemented with: GSFC-S312-P-003, Procurement Specification For Rigid Printed Boards for Space Applications and Other High Reliability Uses (Class 3/A)

IPC-6013, Qualification and Performance Specification for Flexible Printed Boards (Class 3)

IPC-6015 Qualification and Performance Specification for Organic Multichip Module (MCM-L) Mounting and Interconnecting Structures

IPC-6016

IPC-6018, Qualification and Performance Specification for High Frequency (Microwave) Printed Boards (Class 3A)

NASA-STD-8739.1 Workmanship Standard for Staking and Conformal Coating of Printed Wiring Boards and Electronic Assemblies  
“NASA-GSFC Workmanship Requirements For Water Soluble Flux Assurance”, Rev A,  
[http://sma.gsfc.nasa.gov/workmanship/docs/Workmanship\\_Requirements\\_for\\_WSF\\_Assurance\\_11102010.doc](http://sma.gsfc.nasa.gov/workmanship/docs/Workmanship_Requirements_for_WSF_Assurance_11102010.doc)

#### Materials Processing

NASA-STD-6016, Standard Materials and Processes Requirements for Spacecraft

#### Contamination

GSFC 546-WI-8072.1.56A, Contamination Control Procedure for Tape Lift Sampling of Surfaces

IEST-STD-CC1246D, Product Cleanliness Levels and Contamination Control Program

ASTM E1559-09, Standard Test Method for Contamination Outgassing Characteristics of Spacecraft Materials

GSFC 546-WI-8072.1.82A, MOLEKIT2/3 Operating Procedures

GSFC 546-WI-8072.1.80A, Measurement OF BRDF

GSFC 546-WI-8072.1.81A, Determination of Particulate Contamination Using Automated Microscope/Image Analyzer ISO 14644, Cleanrooms and Associated Controlled Environments

#### Mechanical Design

541-PG-8072.1.2B, GSFC Fastener Integrity Requirements

540-PG-8700.2.1A, Design of Dollies, Stands, and Spacecraft Shipping Containers

540-PG-8719.1.1A, Lift Sling Design

ASME Y14.5M-1994, Dimensioning and Tolerancing

500-PG-8700.2.5C GSFC Engineering Drawing Requirements Manual

#### Environmental Testing

GSFC-STD-7000 General Environmental Verification Standard (GEVS)

#### Outgassing

ASTM E-595-07, Standard Test Method for Total Mass Loss and Collected Volatile Condensable Materials from Outgassing in a Vacuum Environment

Outgassing Data for Selecting Spacecraft Materials Online:

<http://outgassing.nasa.gov>

## **V. REFERENCE DOCUMENTS AND SPECIFICATIONS**

The following documents and/or specifications are provided as reference material for the performance of this contract. The latest updated version shall apply:

NASA/SP-2007-6105 Rev1, NASA Systems Engineering Handbook

## VI. ACRONYM LIST

ACS	Attitude Control System
ADP	Automatic Data Processing
ADR	Adiabatic Demagnetization Refrigeration
AETD	Applied Engineering and Technology Directorate
AIMS	Aerial Image Measuring Systems
ANSI	American National Standards Institute
ASAP	Advanced Sensor Analysis Program
ASIC	Application-Specific Integration Circuit
ASTM	American Society for Testing Materials
ATR	Approved Technical Representative
BSDF	Bidirectional Scattering Distribution Function
CAD	Computer Aided Design
CAE	Computer Aided Engineering
CAM	Computer Aided Manufacturing
CCB	Change Control Board
CD	Compact Disk
C&DH	Communication and Data Handling
CDR	Critical Design Review
CIA	Calibration, Integration and Alignment
CLA	Coupled Loads Analysis
CM	Configuration Management
CMMI	Capability Maturity Model® Integration
CNE	Center Network Environment
CODE V	Optical Design Software by Optical Research Associates (ORA)
COTR	Contracting Officer's Technical Representative
CPL	Capillary Pumped Loop
CVCM	Collected Volatile Condensable Materials
DM	Documentation Management
DVD	Digital Video Disk
EDM	Electrical Discharge Machining
EED	Electrical Engineering Division
EEE	Electronic, Electrical, and Electromechanical
ELV	Expendable Launch Vehicle
EMI	Electromagnetic Interference
EMC	Electromagnetic Compatibility
EP	Electrical Propulsion
ESD	Electro-Static Discharge
ETR	Eastern Test Range
ETU	Engineering Test Unit
EVA	Extra-Vehicular Activities
EWR	Eastern/Western Range
F	Fahrenheit

FEM	Finite Element Model
FEMAP	Finite Element Modeling software by Siemens PLM
FFTB	Formation Flying Test Bed
FMEA	Failure Modes and Effects Analysis
FMECA	Failure Modes, Effects, and Criticality Analysis
FPGA	Field Programmable Gate Array
FRB	Failure Review Board
FRED	Optical Software Engineering Package by Photon Engineering
FTA	Fault Tree Analysis
GEVS	General Environmental Verification Standard
GFE	Government Furnished Equipment
GIDEP	Government Interagency Data Exchange Program
GLAD	Physical Optics and Laser Analysis Software by Applied Optics Research
GN&C	Guidance Navigation and Control
GPG	Goddard Procedures and Guidelines
GPIB	General-Purpose Interface Bus
GSE	Ground Support Equipment
GSFC	Goddard Space Flight Center
GUI	Graphical User Interface
ICD	Interface Control Drawing/Document
IDEAS	Software by EDS (formerly by Structural Dynamics Research Corporation)
IEC	International Electrotechnical Commission
IEST	Institute of Environmental Sciences and Technology
IMDC	Integrated Mission Design Center
ISO	International Standard Organization
ISS	International Space Station
ISTD	Instrument Systems and Technology Division
IT	Information Technology
I&T	Integration and Test
IPC	<i>formerly</i> Institute for Interconnecting and Packaging Electronic Circuits
ITS	Information Technology Security
LAN	Local Area Network
LHP	Loop Heat Pipes
LIGA	German Acronym for Lithography, Plating and Molding
MAR	Mission Assurance Requirement
MEMS	Micro Electromechanical
MESA	Mission Engineering and Systems Analysis Division
MIL	Military
MIMO	Multiple Input/Multiple Output
MIP	Mandatory Inspection Point
MLI	Multi-Layer Insulation
MOLEKIT	Molecular Kinetics
MRB	Material Review Board
MSD	Mechanical Systems Division

MSES	Mechanical Systems Engineering Services
N	Newton
NASA	National Aeronautics and Space Administration
NASTRAN	NASA Structural Analysis Program
NDE	Nondestructive Evaluation
NDI	Non-destructive Inspection
NHB	NASA Handbook
NPR	NASA Procedures and Requirements
NSTS	National Space Transportation System
OCL	Optical Calibration Lab
OMS	Orbiter Maneuvering System
ORU	Orbital Replacement Unit
PAR	Product Assurance Requirement
PCB	Printed Circuit Board
PDR	Preliminary Design Review
PFR	Problem Failure Reporting
PG	Procedures and Guidelines
PIC	Procurement Information Circular
PR	Problem Reporting
PRA	Probability Risk Assessment
PWB	Printed Wiring Board
QCM	Quality Control Management
QMS	Quality Management System
REA	Radiation Effects Analysis
RF	Radio Frequency
RMS	STS Remote Manipulator System
R&TD	Research and Technology Development
SEMP	System Engineering Management Plans
SINDA	Systems Improved Numerical Differencing Analyzer
SISO	Single Input/Single Output
SMA	Safety and Mission Assurance
SMAP	Software Mission Assurance Plan
SSPTA	Simplified Space Payload Thermal Analyzer
STD	Standard
STOL	Spacecraft Testing and Operations Language
STOP	Structural-Thermal-Optical Performance
STS	Space Transportation System
TCON	TCON™ is a thermal modeling tool developed by Frederick A. Costello, Inc.
TMG	Thermal Model Generator
TML	Total Mass Loss
TOMS	Task Order Management System
TRASYS	Thermal Radiation Analyzer System
TSS	Thermal Synthesizer Systems
UAV	Unmanned Aerial Vehicle

UNIX	Operating System Software
UV	Ultra Violet
WFSC	WaveFront Sensing and Control
WI	Work Instruction
WTR	Western Test Range
WVR	Water Vapor Regained
WYKO	
ZEMAX	Optical Design Software Program by ZEMAX Development Corporation
ZYGO	Brand name of optical metrology equipment by Zygo Corporation