

**Statement of Work  
for the  
Multi-Mission Radioisotope Thermoelectric Generator**

## **INTRODUCTION**

This Statement of Work (SOW) is for a System Integration Contractor to design, develop, qualify, and produce Multi-Mission Radioisotope Thermoelectric Generators (MMRTGs) for use on future National Aeronautics and Space Administration (NASA) space exploration missions. The MMRTG shall be safe, reliable, long-lived, and suitable for use in various potential NASA space exploration missions, including missions to the surface of Mars (and potentially other planetary bodies) as well as in the vacuum of deep space. The intent is to develop the MMRTG as an option for potential use on future missions including the 2009 Mars Mobile Science Laboratory, the 2011 Outer Planet, and the 2013 Mars Sample Return. The MMRTG shall use thermoelectric materials that have demonstrated extended lifetime and performance, and shall be sized for a heat source composed of eight (8) enhanced General Purpose Heat Source (GPHS) modules. The enhanced GPHS module design to be used on the MMRTG provides added factors of safety in both module impact conditions and in hypervelocity scenarios, such as inadvertent earth gravity assist reentries. The conceptual design of the enhanced GPHS, hereafter referred to as GPHS, includes the addition of a 0.1 inch web in the center of the module between the graphite impact shells and an increase of 0.1 inches in the thickness of the two module broad faces (see Appendix A). Each GPHS module, fueled with plutonium-238 (Pu-238), will provide approximately 250 watts thermal ( $W_{th}$ ) at the beginning of mission.

This SOW for the contractual effort consists of six separate phases. Phase I will be awarded in the initial contract while subsequent phase(s) may be exercised depending on programmatic needs as well as on Contractor performance on previous phase(s). The Phase I effort will be focused on the analysis, design, development, fabrication, and testing of an unfueled Engineering Electrically-heated Thermoelectric Generator (ETG). This phase includes the development of design requirements and specifications for the MMRTG. The Contractor shall test the Engineering ETG to support the design basis for the Flight MMRTG. As part of Phase I, the Contractor shall demonstrate a qualified thermoelectric component fabrication and production capability to produce thermoelectric components to meet design requirements and specifications and proceed to verify their performance, including accelerated testing to determine lifetime performance. The Contractor shall develop analytical tools for performing safety analyses and prepare safety analyses to support ongoing NASA National Environmental Policy Act (NEPA) activities.

The Phase II Option will be focused on the analysis, design, fabrication, and testing of a Qualification ETG that will be used to flight qualify the MMRTG for space missions. Based on the results of Phase I, the design requirements and specifications shall be updated. The

Contractor shall complete the final design, fabricate, and test the Qualification ETG. As part of Phase II, the Contractor shall demonstrate that the thermoelectric component fabrication process is qualified to produce high quality, uniform thermoelectric components that meet design requirements and specifications for various space exploration environments. The phase includes the fueling and testing of the Qualification ETG at the Department of Energy (DOE) fueling and test facility. In Phase II, the Contractor shall continue to perform safety analyses to support NASA's NEPA activities and prepare a Preliminary Safety Analysis Report (PSAR) to support the interagency launch approval process for use of the MMRTG.

The Phase III-V Options include the Contractor's efforts to produce Flight ETGs to achieve specific mission objectives. The Contractor shall deliver government accepted Flight ETGs to the DOE fueling and test facility. These phases shall include the spacecraft integration, preparation of a Final Safety Analysis Report (FSAR), and support of the launch approval and ground operations activities. The Phase VI Option will be for a spare Flight MMRTG and may be exercised in concert with the execution of the Phase III, IV, and/or V Options.

For planning purposes, the Contractor should assume for the Phase III Option two (2) Flight MMRTGs for a potential 2009 Mars Mobile Science Laboratory mission; for the Phase IV Option, the Contractor should assume three (3) Flight MMRTGs for a potential 2011 Outer Planet mission; for the Phase V Option, the Contractor should assume two (2) Flight MMRTGs for a potential 2013 Mars Sample Return mission; and for the Phase VI Option, the Contractor should assume one (1) spare Flight MMRTG. The launches are assumed to be from the Kennedy Space Center/Cape Canaveral Air Force Station (KSC/CCAFS) on an Expendable Launch Vehicle (ELV). The Contractor shall develop a preliminary schedule, including major milestones, for all phases of the contract utilizing the firm dates and time constraints provided in Attachment IA of this SOW. This schedule shall be approved by DOE prior to contract award.

## SCOPE

The Contractor shall serve as System Integration Contractor for the DOE MMRTG project. The Contractor shall:

- Develop MMRTG Requirements and Specifications and Test Plans for the Engineering, Qualification, and Flight ETGs and MMRTGs.
- Develop qualification and acceptance test levels for the ETGs and MMRTGs.
- Perform structural, thermal, and thermoelectric design analyses of the MMRTG in order to support a definitive design basis in such areas as system response to launch dynamic loads, heat source support preload, thermal interface definition, radiation properties, and handling requirements during and prior to launch.
- Develop power predictions for various mission profiles, including various launch dates and mission durations.
- Develop the design and establish engineering documentation for the MMRTGs and ground support equipment.
- Demonstrate a thermoelectric component manufacturing capability for fabricating thermoelectric materials and thermoelectric components. Provide for the training and qualification of operators, supervisors, and inspectors.
- Qualify the production facility and procedures by manufacturing qualification lots of thermoelectric components and by the fabrication and test of several qualification lots to determine lifetime performance.
- Fabricate, assemble, and test an Engineering ETG to support the design basis for the MMRTG.
- Fabricate, assemble, and test a Qualification ETG and ship to the DOE facility for fueling and testing to qualify the MMRTG.
- Provide technical review and oversight of the ETG/MMRTG handling, fueling, and acceptance testing at the DOE fueling and test facility as defined in Interface Working Agreements (IWAs). The Contractor shall also interface with the various Government heat source production facilities per the IWAs.
- Fabricate ground support equipment, as required, for use at the DOE fueling and test

facility and at the launch site.

- Prepare safety assessments of the MMRTG and support analyses and documentation for the NASA NEPA Environmental Impact Statement (EIS) process based upon mission/launch vehicle databooks. Prepare Safety Analysis Reports and participate in the Interagency Nuclear Safety Review Panel (INSRP) reviews with DOE and NASA to obtain launch approval.
- Prepare a Safety Test Plan and provide test hardware and engineering oversight for safety tests conducted at Government laboratories or elsewhere.
- Provide launch site support for the receipt, storage, maintenance, and flight preparation of MMRTGs; spacecraft integration; support activities; and testing of MMRTGs.
- Participate in special studies as requested by the Office of Space and Defense Power Systems.
- Establish project management, project control and reporting, quality assurance, and environmental and reliability activities required for this contract. National, state, and local safety, health, and environmental laws shall be adhered to in the manufacture of ETGs.

## **PHASE I**

### **1.0 DESIGN, DEVELOPMENT, FABRICATION, AND TESTING OF AN ENGINEERING ETG**

In Phase I, the Contractor shall design, develop, fabricate, and test an Engineering ETG to support the design basis of the Flight MMRTG. The Contractor shall develop requirements and specifications for the Flight MMRTG. The Contractor shall demonstrate through analyses and testing that a Flight MMRTG design can be developed that would meet the DOE approved requirements and specifications. The results of Phase I will form the technical basis for proceeding to Phase II for qualifying the design for flight use.

#### **1.1 System Integration**

The Contractor shall conduct system integration activities for all technical aspects of the project, including interfacing with NASA, launch vehicle supplier, DOE laboratories, launch site operations, and others as necessary. The Contractor shall prepare for and attend interface meetings required to perform the system integration activities, including participation as required at NASA review meetings. The Contractor shall prepare and implement, or assist DOE in preparing and implementing, interface working agreements with NASA, DOE laboratories, and others.

#### **1.2 MMRTG Requirements and Specifications Development**

The Contractor shall develop preliminary design, performance, environment, integration, and test requirements for the MMRTG. The Contractor shall support a MMRTG Preliminary Requirements Review. DOE shall approve the MMRTG Preliminary Requirements.

The Contractor shall develop a Preliminary Flight ETG Product Specification and a Preliminary Flight MMRTG Product Specification based on the MMRTG Preliminary Requirements. As part of this effort, the Contractor shall define environments that the MMRTG will be exposed to and identify the test and analysis requirements that assure the MMRTG will operate within these environments. These environments include those encountered in deep space and on the surface of Mars. DOE shall approve these specifications. The Contractor shall also develop a preliminary hierarchical listing of requirements and specifications for subsystems, components, and ground support equipment.

For planning purposes, a preliminary set of design and performance requirements for the MMRTG for deep space and Mars exploration missions are provided below:

- Design: The MMRTG design shall be based on the use of eight (8) enhanced GPHS modules to provide at least 110 watts at beginning of mission (BOM).
- Environment: The MMRTG shall operate in environments encountered in deep space and on the surface of Mars.
- Lifetime: The MMRTG shall provide power for missions that could last at least 14 years.
- Power: BOM power shall be estimated by the Contractor and power be plotted for a 14 year duration. The BOM GPHS thermal inventory is  $250 \pm 6 W_{th}$ . In developing the conceptual design, the Contractor must define any assumed rates of MMRTG power decay over the entire range of operations, including Pu-238 decay, and a plot of current vs. voltage curve.
- Mass: MMRTG shall be as small and light as possible while maximizing specific power (W/kg).
- Operating Voltage: MMRTG design shall operate over a range 23-36  $V_{dc}$  and provide near maximum power over the life of the mission to a spacecraft bus operating at nominal voltage of  $28 \pm 0.2 V_{dc}$ .
- Reliability: MMRTG shall be designed to maximize reliability, including use of series-parallel circuitry.

The MMRTG design shall consider several other parameters:

- MMRTG shall try to maximize power during launch (e.g., produce not less than 80% of nominal power during launch, returning to 100% of nominal power after the end of the launch sequence).
- The overall size of the MMRTG must be such that it will fit within the maximum acceptable envelope for the DOE shipping container (USA/9904/B(U)-F-85 Radioisotope Thermoelectric Generator Package) that is used to transport the fueled systems.
- MMRTG shall be designed to allow for multiple Venus gravity assist maneuvers.
- MMRTG shall be designed to withstand launch loads for the new class of ELVs and landing loads for various missions, for example,  $0.2g^2/Hz$  vibration and 40 g acceleration loads.
- The MMRTG shall be designed to EMI/EMC Standard 461C and meet magnetics requirements of 25nT at 1 meter (for those missions with a magnetometer specific requirement). Compensating magnets can be considered.
- A 4A or 4B sterilization requirement may be required for a Mars mission application.

- The Mars surface environment is a 6-10 torr CO<sub>2</sub> atmosphere with daily temperatures ranging from 170-270 K with varying amounts of suspended and deposited dust.
- MMRTG shall be designed to allow complete waste heat removal by cooling loops or by radiation heat transfer to space or any combination of both methods (when required for specific missions).
- MMRTG shall be designed to withstand the radiation environments that will be encountered on missions to Mars. The Contractor shall also identify the impacts and approaches for the MMRTG to withstand a total dose of up to 4Mrad (Si) behind 100 mils of aluminum, when required for specific missions.
- Means shall be taken to avoid single point failures.
- The Contractor shall also identify the impacts and approaches for the MMRTG to withstand a Titan atmosphere.

In developing the designs and conducting their analysis, the Contractor shall consider a reasonable range of accident environments established jointly by NASA and DOE. The Contractor shall consider safety in all aspects of system design and implementation. Those aspects include, but are not limited to, the following:

- The Contractor shall design the MMRTG to minimize the impact to safety that the MMRTG components may have on the integrity of the GPHS modules and fuel clads during an accident. Throughout the design process, the Contractor shall analyze the MMRTG components to evaluate their effect on the GPHS modules and fuel clads during a reasonable range of potential accident scenarios established jointly by NASA and DOE.
- The MMRTG design in and of itself shall not impede the free and clear release of the GPHS modules under a reasonable range of inadvertent Earth reentry conditions established jointly by NASA and DOE.
- After meeting the structural load requirements established jointly by NASA and DOE for the MMRTG the Contractor shall, for a reasonable range of potential accident scenarios as established jointly by NASA and DOE, give consideration to passive design features that would facilitate the free and clear release of the GPHS modules when exposed to the reasonable range of environments associated with those accidents.

These preliminary design and performance requirements are for planning purposes only and are subject to change. Detailed requirements and specifications are to be developed by the Contractor while interfacing with DOE, NASA and others.

### **1.3 Flight MMRTG Preliminary Design**

The Contractor shall develop a preliminary design for the Flight MMRTG that will meet the requirements and specifications developed in section 1.2. Engineering analyses and trade off studies shall be performed and documented. The Contractor shall consider in the design: shipping requirements for the ETG to the DOE fueling and test facility; handling, fueling, and testing operations at the DOE fueling and test facility; transportation requirements to the launch site; ground operations at the launch site; and safety analysis.

In addition to power, weight, and size, the Contractor shall consider reliability as a major system parameter to be evaluated in the trade off studies. Specifications for subsystems and components, such as thermoelectric components, are to be defined and include test and acceptance requirements. The Contractor shall specify, to the maximum extent possible, the use of materials and technologies that have a demonstrated performance and successful reliability history in similar applications.

The evolution of the preliminary design shall be presented as part of the periodic project review meetings. The Contractor shall conduct a formal preliminary design review and record and closeout action items from the review. The design review shall address: how the preliminary design will meet the requirements and specifications, the fabrication of the ETG, the test program to demonstrate the design meets the requirements and specifications, fueling and testing operations at the DOE fueling and test facility, safety analysis, integration with the spacecraft, transportation operations, ground operations at the launch site, performance during all phases of the mission including launch and other topics as identified by the preliminary design review committee. DOE approval of the preliminary design is required.

### **1.4 Qualified Thermoelectric Component Fabrication**

The Contractor shall prepare a Thermoelectric Component Qualification Plan and demonstrate a qualified thermoelectric component fabrication and production capability to produce thermoelectric components that meet the specifications developed in section 1.3. The demonstration shall include the following:

#### **1.4.1 Fabrication Equipment**

The Contractor shall identify, fabricate and/or procure the required equipment to fabricate and test the thermoelectric components. The equipment shall be made ready for operation. This includes the tooling and fixtures necessary for production.

#### **1.4.2 Fabrication Procedures and Operator Training**

The Contractor shall develop fabrication procedures for thermoelectric components.

DOE or DOE's designated official shall approve these procedures. The Contractor shall train and certify operators to operate the equipment and tooling in accordance with the approved fabrication procedures.

#### **1.4.3 Thermoelectric Components Materials**

The Contractor shall identify and qualify vendors for procured components and materials.

#### **1.4.4 Qualified Thermoelectric Components Fabrication**

The Contractor shall conduct a pre-production run to demonstrate that the production process uniformly and reliably produces thermoelectric components that meet the specifications developed in section 1.3. Destructive as well as non-destructive examination and testing of the thermoelectric components shall be performed to determine and confirm metallurgical condition, performance parameters, and overall condition and properties of the thermoelectric components. The test results shall be documented and submitted to DOE. Upon DOE's approval, the Contractor shall proceed to fabricate two lots of thermoelectric components. Production yields shall be based on the second lot of thermoelectric components. Following the first run, all refinements to further define procedures and processes must be submitted to DOE for approval prior to starting the second run.

A Thermoelectric Component Test Plan shall be prepared for DOE approval. Thermoelectric components are to be tested at prototypic temperatures and at higher temperatures to provide accelerated test results. These test results shall be compared to model predictions and reported to DOE at project review meetings and in monthly progress reports

#### **1.4.5 Thermoelectric Component Fabrication**

Based on DOE's approval, the Contractor shall proceed to produce thermoelectric components for the Engineering ETG. Sufficient thermoelectric components shall be produced to meet expected yields and to provide spares.

### **1.5 Assembled Engineering ETG**

The Contractor shall prepare an ETG Fabrication Plan identifying the equipment, process operations, and test and inspection operations. The Contractor shall fabricate and assemble an Engineering ETG based on the Flight MMRTG Preliminary Design developed in section 1.3. The Engineering ETG shall be electrically heated and prototypic of the Flight ETG (form, fit and function). Vendors shall be identified and qualified for procured components and materials. The Contractor shall develop fabrication procedures for assembling the Engineering ETG and train and certify operators to operate the equipment

and tooling in accordance with those procedures. A readiness review shall be conducted before proceeding to fabrication. DOE approval is required before fabrication is initiated. The Contractor shall identify critical components and, if warranted, provide spares of these components to provide for quick repair or replacement.

In support of this effort, the Contractor shall design, fabricate, and qualify an electrical heater that simulates the GPHS heat source. The electrical heater shall be designed and analyzed to determine the parasitic heat losses during test operations so that the efficiency of the Engineering ETG can be calculated and compared with predictions. Spare heaters are to be provided.

### **1.6 Engineering ETG Tests**

The Contractor shall conduct tests to demonstrate the capability of the Engineering ETG design to meet DOE approved requirements and specifications. An Engineering ETG Test Plan shall be prepared detailing test requirements and identifying pass/fail criteria for each test. DOE shall approve the Engineering ETG Test Plan.

Following testing, the Contractor shall perform diagnostic examinations to determine the physical and electrical condition of the Engineering ETG. Any defective condition or malfunction shall be analyzed with recommendations to correct the condition. Corrective actions shall be taken to prevent recurrence.

The Contractor shall prepare an Engineering ETG Test Report. The Engineering ETG Test Report shall be a stand-alone document encompassing the Engineering ETG Test Plan, testing history, test results, acceptability of results, and recommendations for changes to the design.

### **1.7 Fueling, Transportation and Ground Support Tooling and Equipment**

The Contractor shall identify: the tooling and equipment that will be required to transport the ETGs to the DOE fueling and test facility; the tooling and equipment required to handle, fuel, and test (including life-testing) the generators at the DOE fueling and test facility; the tooling and support systems to load, monitor, and transport a MMRTG to the launch site; and the ground support equipment required to handle, monitor, and transport the MMRTG at the launch site.

### **1.8 NEPA and Safety Support**

During Phase I, the Contractor shall prepare the safety analysis tools required to conduct nuclear risk assessments in support of NASA's NEPA review process and the interagency launch approval process. During this phase, the Contractor shall participate in the review of NASA mission/launch vehicle databook(s), perform safety analysis, and prepare

documentation as required to support the NASA NEPA and interagency launch approval processes.

### **1.8.1 Safety Analysis**

The Contractor shall perform an integrated risk analysis for input to NASA's NEPA process that assesses and quantifies the radiological risk to humans resulting from the potential release, dispersion, and uptake of plutonium dioxide used in the MMRTGs following postulated launch accidents. The material in the analysis may be a combination of scaling from previous risk assessments and new analysis as appropriate. This analysis shall also provide estimates of potential land contamination. Launch vehicles to be considered for the integrated risk analyses are the ELVs. The risk analyses shall be described in a report that provides fuel release quantities (source term), health consequences, radiological health risk probabilities, and estimates of land contamination.

For both the NEPA EIS risk assessment and the interagency launch approval processes, DOE will provide an assessment of any risks associated with the use of Light Weight Radioisotope Heater Units (LWRHUs) and other minor source terms on the mission(s). The Contractor is responsible for integrating the risk due to LWRHUs and any minor source terms into their reports to provide an integrated risk estimate for the mission(s).

The Contractor shall support the review of safety analysis documentation by the INSRP and/or other appropriate reviewers as indicated by DOE. This includes providing assistance to INSRP in conducting their investigations and review.

### **1.8.2 Safety Test Support**

The Contractor shall support the development of a MMRTG safety test program. The Contractor shall prepare a Preliminary Safety Test Plan describing specific safety test, safety test requirements, and safety test hardware that shall be required to support the interagency launch approval process.

## **1.9 Special Studies**

This task consists of the design and analysis activities required to perform applicable studies for DOE. The Contractor shall produce drawings, requirements, and specification documents to support these studies. Specific areas of required technical refinement shall be identified by the Contractor, including such areas as safety, efficiency, fabrication and testing, analysis of flight data, and performance and design improvements. The Contractor shall also define test requirements, review test plans, conduct tests, and analyze test data as applicable to qualify the proposed refinements or improvements. Those areas or items specifically approved by DOE shall be studied and necessary experiments conducted to assess feasibility and payoff for the application. DOE will identify the specific applications

and user contacts. An effort not to exceed three (3) man-years per year of engineering staff time plus travel is anticipated for this task.

## **1.10 Project Management**

The Contractor shall provide for the overall management of the contracted project effort. This management function shall include all necessary activities to plan and manage the contracted and subcontracted efforts as well as to provide all necessary day-to-day interfaces and support to the project.

The Contractor shall implement a tailored project management system to set forth the principles and requirements that govern the development, approval, and execution of the contractual effort in accordance with DOE Order 4700.1 "Project Management System."

### **1.10.1 Project Management Plan**

The Contractor shall update and finalize the Project Management Plan and Work Breakdown Structure (WBS) Dictionary provided with the proposal. The Contractor shall prepare a detailed baseline plan using Primavera Project Planner© (P3). The baseline plan shall be comprised of each element of the WBS defined into specific Contractor activities. Each activity shall include a description of the work, the established budget, the duration of the activity, the assigned WBS code, the organizational breakdown code, and predecessor and successor activities. Schedule dates, including early start, early finish, late start, and late finish dates, shall be shown. The Contractor shall measure performance monthly against the baseline plan using P3.

Orbital Sciences Corporation (OSC), DOE's designated contractor, will develop a Program Baseline Plan that will incorporate input from all program participants. In developing the baseline plan for this contract, the Contractor shall coordinate the structure of their baseline plan with OSC so that the Contractor's baseline plan can be integrated into the Program Baseline Plan. The level of detail to be included and reported to in the Program Baseline Plan shall be agreed to by the Contractor and DOE.

### **1.10.2 Program Reviews**

The Contractor shall plan and conduct formal reviews required under this contract and shall provide agendas and document the results of the review meetings.

The Contractor shall develop a Review Plan to be included in the Project Management Plan. The Review Plan shall provide a list of proposed reviews and a description for each

review. For Phase I, the Review Plan shall include, but is not limited to, the following:

- MMRTG Preliminary Requirements Review
- Flight MMRTG Preliminary Design Review

The Contractor shall prepare an agenda for each of the reviews not less than four (4) weeks prior to the scheduled review. The Contractor shall provide reviewers a Review Data Package not less than 2 weeks prior to each review. The Contractor shall document the results of the review by means of minutes and an action item summary not more than ten (10) working days after the review. The Contractor shall maintain a tracking system for the action items until each action item is closed.

### **1.10.3 Management Meetings**

The Contractor shall participate in monthly management level project meetings held with the DOE representative at the Contractor's facility to review project status in terms of technical progress against schedule and cost performance, to review action item status, and to assign new action items for resolution as appropriate. When other reviews (e.g., quarterly reviews) coincide with the monthly meetings, they shall replace monthly project meetings. These meetings shall be chaired by the Contractor's project manager or designated alternate. Contractor support personnel shall attend as required. The Contractor shall provide the agenda for each meeting to DOE for approval. The Contractor shall prepare meeting minutes, including action items and distribute them within one week of the meeting. Informal technical interchange meetings will also be held as needed.

### **1.10.4 Management Information and Reporting System**

The Contractor shall implement and maintain a management information and performance measurement reporting system that shall be consistent with DOE Contractor reporting requirements provided in Attachment II. The Contractor shall provide a brief (typically less than three pages in length) weekly progress report to DOE. Critical issues shall be identified in this report.

The Contractor shall implement and maintain a commitments and agreements database file. These files shall include commitments and agreements with DOE, other Federal agencies, laboratories, and their contractors as necessary.

The Contractor shall implement and maintain an engineering data file (e.g., internal project directives, project plans, travel reports, engineering memos, analyses, test reports, problem/failure reports, drawings, presentations, etc.) throughout the period of contract performance. The Contractor shall update monthly the index of the file. The Contractor shall make available specific file items to DOE on request.

The Contractor shall report on a monthly basis an assessment of work in progress. The Contractor shall measure and report on a monthly basis actual project expenditures and percent complete of work performed against the approved baseline plan using P3. In addition, a cost to complete calculation should also be reported. Actual project expenditures may be reported using software that can export cost data to P3. Reporting shall be consistent with the DOE Program Baseline Plan to an agreed-upon level of detail from the Contractor's WBS. The Contractor shall backup their current plan and forward the backed-up plan either by email or by overnight mail on portable electronic media to Orbital Sciences Corporation for integration into the DOE Program Baseline Plan.

### **1.10.5 Interface with Government Laboratories**

The Contractor shall establish and maintain interface activities with Government laboratories and facilities concerning fuel production and processing, heat source fabrication and assembly, and MMRTG fueling and testing. The interface with the DOE fueling and test facility shall be defined in an IWA among (1) DOE Headquarters and the cognizant field office, (2) the DOE fueling and test facility, and (3) the Contractor. The IWA shall be prepared and maintained by the Contractor, jointly agreed upon by the DOE fueling and test facility and the Contractor, and approved by DOE. The Contractor's responsibilities and authority shall be defined in this document.

## **1.11 Quality Assurance and Reliability**

### **1.11.1 Quality Assurance**

The Contractor shall develop and implement a Quality Assurance Program (QAP) in accordance with the Contractor Requirements Document (CRD), Attachment 1 of DOE Order 414.1A, "Quality Assurance", and SDPS/PQAR-1 (Revision 4), "Space and Defense Power Systems Programmatic Quality Assurance Requirements for Space and Terrestrial Nuclear Power Systems." The Contractor's QAP shall use national and international consensus standards (e.g., NQA-1, ISO 9001, etc.) in implementing quality assurance requirements. The scope, depth, and rigor of the QAP application shall be tailored by the Contractor based on the importance to safety and commensurate with contractual activities. The QAP shall include the policies and procedures for implementation of the QAP based on engineering and quality activities applicable to the specific contractual phase and shall be provided to DOE. The details of the QAP shall be documented in a Quality Assurance Program Plan (QAPP).

### **1.11.2 Reliability**

The Contractor shall establish, implement, and maintain a Reliability Program. The detail of the reliability program shall be documented in a Reliability Program Plan in accordance with OSNP-3, "Reliability Program Requirements for Space and Terrestrial Nuclear Power

Systems.” The reliability tasks shall include Reliability in Design, Failure Mode Effects and Criticality Analysis (FMECA), Failure Reporting documentation, etc., but will not include the performance of analyses and model development as required by OSNP-3, Section 4.4.

The Reliability Program Plan shall delineate the Contractor’s methodology for planning, establishing, implementing, documenting, and maintaining control of a formal reliability program that will result in reliable mission performance with appropriate documentation. The plan shall demonstrate compliance with the requirements of those sections of OSNP-3 that will be performed during phases of the project.

The Contractor shall prepare a system FMECA, evaluate all test results in support of the FMECA for the system, address the impact of test results on the FMECA for the system, and identify all credible Single Point Failures (SPFs). All SPFs must be documented and approved by DOE.

The Contractor shall establish a closed-loop failure and corrective action system. Each failure shall be documented as required by OSNP-3. All failures shall be reported to DOE and discussed as part of the monthly progress reports. The Contractor shall list root cause and recommendations for corrective action to prevent recurrence of the failure, if applicable, as explained in OSNP-3.

### **1.12 Resident Representative at Contractor Facilities**

The Contractor shall supply office facilities and services to accommodate two DOE on-site representatives. Facilities are to include offices, desks, personal computers with email and Internet capabilities, tables, file cabinets, phones with voicemail, and copying and fax services. The Contractor shall provide unescorted badge privileges for the on-site representative(s) for access to all project activity areas.

## **PHASE II (OPTION)**

### **2.0 DESIGN, FABRICATION, AND TESTING OF A QUALIFICATION ETG**

In the Phase II Option, the Contractor shall design, fabricate, and test a Qualification ETG to qualify the design of the MMRTG for flight. Based on Phase I activities, the requirements and specifications for the Flight MMRTG shall be updated. The Qualification ETG shall be shipped to the DOE fueling and test facility for fueling and qualification testing. The Contractor shall demonstrate through analyses and these test results that the Flight MMRTG design is flight qualified. The results of Phase II will form the technical basis for proceeding to mission specific phase(s).

#### **2.1 System Integration**

The Contractor shall continue to conduct system integration activities for all technical aspects of the project, including interfacing with NASA, launch vehicle supplier, DOE laboratories, launch site operations, and others as necessary. The Contractor shall prepare for and attend interface meetings required to perform the system integration activities, including participation as required at NASA review meetings. The Contractor shall prepare and implement, or assist DOE in preparing and implementing, interface working agreements with NASA, DOE laboratories, and others.

#### **2.2 MMRTG Requirements and Specifications**

The Contractor shall update and finalize the design, performance, spacecraft integration, and test requirements for the MMRTG developed in Phase I to incorporate necessary changes based on Phase I test results and new information. The Contractor shall support a MMRTG Requirements Review. DOE shall approve the MMRTG Requirements.

The Contractor shall update and finalize the Flight ETG Product Specification and the Flight MMRTG Product Specification based on the updated MMRTG Requirements. DOE shall approve these specifications. The Contractor shall also update and finalize the hierarchical listing of requirements and specifications developed in Phase I.

#### **2.3 Flight MMRTG Final Design**

The Contractor shall develop a final design for the Flight MMRTG that will meet the requirements and specifications developed in section 2.2. Engineering analyses and trade off studies shall be performed and documented. The Contractor shall consider in the design: shipping requirements for the ETG to the DOE fueling and test facility; handling, fueling, and testing operations at the DOE fueling and test facility; safety analysis; transportation requirements to the launch site; and ground operations at the launch site.

In addition to power, weight, and size, the Contractor shall consider reliability as a major system parameter to be evaluated in the trade off studies. Subsystem and components, such as thermoelectric components, are to be specified with test and acceptance requirements. The Contractor shall specify, to the maximum extent possible, the use of materials and technologies that have a demonstrated performance and successful reliability history in similar applications.

The evolution of the final design shall be presented as part of the periodic project review meetings. The Contractor shall conduct a formal final design review and record and closeout action items from the review. The design review shall address how: the final design will meet the requirements and specifications, the fabrication of the ETG, the test program to demonstrate the design meets the requirements and specifications, fueling and testing operations at the DOE fueling and test facility, safety analysis, integration with the spacecraft, transportation operations, ground operations at the launch site, performance during all phases of the mission including launch and other topics as identified by the final design review committee. DOE approval of the final design is required.

#### **2.4 Qualified Thermoelectric Components Fabrication**

The Contractor shall demonstrate that the thermoelectric component fabrication process continues to uniformly and reliably produce qualified thermoelectric components. If requested, the Contractor shall conduct a readiness review before proceeding to fabrication. This review shall include procedures, personnel qualification, personnel certification and facilities readiness. With DOE's approval, the Contractor shall proceed to produce thermoelectric components for the Qualification ETG.

The Contractor shall continue testing the thermoelectric components that were initiated in Phase I to further determine their lifetime performance. The Contractor shall prepare and issue a report on the performance of the thermoelectric components.

#### **2.5 Assembled Qualification ETG**

The Contractor shall update the ETG Fabrication Plan prepared in Phase I and fabricate and assemble a Qualification ETG based on the Flight MMRTG Final Design developed in section 2.3. The Qualification ETG shall be representative of the Flight ETG. Vendors shall be identified and qualified for procured components and materials. The Contractor shall update the procedures for assembling the ETG and train and certify operators to operate the equipment and tooling in accordance with those procedures. A readiness review shall be conducted before proceeding to fabrication. DOE approval is required before fabrication is initiated. The Contractor shall identify critical components and, if warranted, provide spares of these components to provide for quick repair or replacement.

## **2.6 Qualification ETG Tests**

The Contractor shall conduct tests to demonstrate the capability of the Qualification ETG design to meet DOE approved requirements and specifications. A Qualification ETG Test Plan shall be prepared by the Contractor and approved by DOE. The Qualification ETG Test Plan shall provide detailed testing requirements and identify pass/fail criteria for each test. The Qualification ETG Test Plan shall also include requirements for life testing of the Qualification MMRTG. The types of tests to be performed, the test levels, and qualification and acceptance criteria are to be developed as part of the system integration activities and design requirements and specification development.

Following testing, the Contractor shall perform diagnostic examinations to determine the physical and electrical condition of the Qualification ETG. Any defective condition or malfunction shall be analyzed with recommendations to correct the condition. Corrective actions shall be taken to prevent recurrence.

The Contractor shall prepare a Qualification ETG Test Report. The Qualification ETG Test Report shall be a stand-alone document encompassing the Qualification ETG Test Plan, testing history, and test results. The report shall provide objective evidence that the Qualification ETG meets the requirements and specifications developed in section 2.2.

Following testing and DOE buy-off of the ETG, the Contractor shall ship the Qualification ETG to the DOE fueling and test facility.

## **2.7 Fueling and Qualification Testing at the DOE Fueling and Test Facility**

A Qualification MMRTG Test Plan shall be prepared and approved by DOE. The Contractor shall prepare detailed handling, processing, fueling, and qualification testing specifications for the DOE fueling and test facility to enable development of corresponding procedures. The DOE fueling and test facility personnel will provide input to the Contractor for these specifications. Fueling and qualification testing procedures will be prepared by the DOE fueling and test facility, reviewed by the Contractor, and approved by DOE.

The Contractor shall support the fueling and testing of the Qualification MMRTG at the DOE fueling and test facility. The Contractor shall provide oversight of the fueling and testing operations (e.g., procedure review, tooling and fixture review, walkthroughs, readiness reviews, etc.).

Following testing, the Contractor shall coordinate with the DOE fueling and test facility to perform non-destructive diagnostic examinations to determine the physical and electrical condition of the Qualification MMRTG. Any defective condition or malfunction shall be analyzed with recommendations to correct the condition.

The Contractor shall prepare a Qualification MMRTG Test Report. The Qualification MMRTG Test Report shall be a stand-alone document encompassing the Qualification MMRTG Test Plan, testing history, and test results. The report shall provide objective evidence that the Qualification MMRTG meets the requirements and specifications developed in section 2.2.

## **2.8 Life-Testing and Performance Model Verification**

The Contractor shall continue testing the thermoelectric components that were initiated in Phase I to further determine their lifetime performance as well as to validate lifetime model predictions. The Contractor shall also predict the lifetime performance of the MMRTG. The Contractor shall coordinate with the DOE fueling and test facility to obtain test data from the Qualification MMRTG to validate the model predictions. The Contractor shall issue results of the lifetime model predictions and performance of the thermoelectric components and the MMRTG. The information reported should include, but is not limited to, performance, anomalies, analysis of test results, performance predictions and model validation results.

## **2.9 Fueling, Transportation and Ground Support Tooling and Equipment**

The Contractor shall design and fabricate the tooling and equipment to transport the ETG to the DOE fueling and test facility. The Contractor shall provide specifications for the DOE fueling and test facility to procure and fabricate tooling and equipment for handling, fueling and testing the Qualification and Flight MMRTGs and for transporting the MMRTGs to the launch site. The Contractor shall design the ground support equipment required to handle, monitor, and transport the MMRTG at the launch site. The Contractor shall provide specifications to the DOE fueling and test facility to produce and fabricate the ground support equipment that will be required at the launch site.

## **2.10 MMRTG Mass and Thermal Models and a Fueling Mock-up**

The Contractor shall design and build a mass model, a thermal model, and a fueling mock-up. The mass model shall be constructed to duplicate the mass and center of gravity of a Flight MMRTG, and shall simulate mechanical interfaces with the spacecraft.

The thermal model shall be constructed to provide a simulation of the thermal properties (e.g., surface temperatures) of a Flight MMRTG. The thermal model shall be electrically heated, capable of generating the thermal output of a Flight MMRTG and dissipating the heat at a temperature that approximates the average external surface temperature of an operating MMRTG in both a Mars planetary and outer space environment. It shall also simulate mechanical interfaces with the spacecraft.

The full-size fueling mock-up shall be sufficiently representative of a Flight MMRTG to

enable the checkout of fueling and test fixtures used at the DOE fueling and test facility.

## **2.11 NEPA and Launch Safety**

The Contractor shall complete those activities related to the development of safety analysis tools to be used in the NEPA EIS and the interagency launch approval processes that were not finalized in Phase I.

The Contractor shall continue performing safety analyses involving nuclear risk assessments to support NASA's NEPA requirements and the interagency launch approval process. These safety analyses shall address the MMRTG response to blast, fragment, fire, ground/mechanical impact, and reentry environments arising from potential failures in various accident scenarios. The Contractor shall perform structural and thermal analyses, as appropriate, to assess these interactions. Modeling of dynamics of MMRTG hardware, launch vehicle, and spacecraft components may be required to assess the random nature of events that could occur during potential accident scenarios. During this phase, the Contractor shall support databook review activities.

### **2.11.1 Safety Analysis for Launch Approval Process**

The Contractor shall perform an integrated risk analysis that assesses and quantifies the radiological risk to humans resulting from the potential release, dispersion, and uptake of plutonium dioxide used in the MMRTGs following postulated launch accidents. This analysis shall also provide estimates of potential land contamination. Launch vehicles to be considered for the integrated risk analyses are the ELVs. The risk analyses shall be described in a report that provides fuel release quantities (source term), health consequences, radiological health risk probabilities, and estimates of land contamination.

For both the NEPA EIS and the interagency launch approval processes, DOE will provide an assessment of any risks associated with the use of LWRHUs and other minor source terms on the mission(s). The Contractor is responsible for integrating the risk due to LWRHUs and any minor source terms into their reports to provide an integrated risk estimate for the mission(s).

The Contractor shall issue the PSAR for the first mission, which will be designated by the start of Phase II. The Contractor shall support the review of such documentation by the INSRP and/or other appropriate reviewers as indicated by DOE. This includes providing assistance to INSRP in conducting their investigations and review.

### **2.11.2 Safety Test Support**

The Contractor shall update and finalize the Preliminary Safety Test Plan developed in Phase I. The Contractor shall continue to provide support in the planning of the overall

MMRTG safety test program. The Contractor shall provide support for the actual testing and analysis of test results. The testing may evaluate the generator design, hardware, and interactions with the GPHS modules at the system level under various accident environments.

The Contractor shall provide safety test hardware consistent with the Safety Test Plan. The hardware shall be representative of the MMRTG hardware and consist of all elements that could affect the response of the GPHS modules and fueled clads to accident environments.

## **2.12 Special Studies**

This task consists of the design and analysis activities required to perform applicable studies for DOE. The Contractor shall produce drawings, requirements, and specification documents to support these studies. Specific areas of required technical refinement shall be identified by the Contractor, including such areas as safety, efficiency, fabrication and testing, analysis of flight data, and performance and design improvements. The Contractor shall also define test requirements, review test plans, conduct tests, and analyze test data as applicable to qualify the proposed refinements or improvements. Those areas or items specifically approved by the DOE shall be studied and necessary experiments conducted to assess feasibility and payoff for the application. The specific applications and user contacts will be identified by DOE. An effort not to exceed three (3) man-years per year of engineering staff time plus travel is anticipated for this task.

## **2.13 Project Management**

The Contractor shall provide for the overall management of the effort. The Contractor shall implement a tailored project management system to set forth the principles and requirements that govern the development, approval, and execution of the contractual effort in accordance with DOE Order 4700.1, "Project Management System."

### **2.13.1 Project Management Plan**

The Contractor shall update, as needed, the Project Management Plan, WBS, and the baseline plan developed in Phase I. The Contractor shall measure monthly performance against the DOE approved baseline plan using P3. The baseline plan shall be comprised of each element of the WBS defined into specific Contractor activities. Each activity shall include a description of the work, the established budget, the duration of the activity, the assigned WBS code, the organizational breakdown code, and predecessor and successor activities. Schedule dates, including early start, early finish, late start, and late finish dates, shall be shown. The Contractor shall update assigned activities on a monthly basis.

OSC, DOE's designated contractor, will develop a Program Baseline Plan that will incorporate input from all program participants. In updating the baseline plan for this

contract, the Contractor shall coordinate the structure of their baseline plan with OSC so that the Contractor's baseline plan can be integrated into the Program Baseline Plan. The level of detail to be included and reported to in the Program Baseline Plan shall be agreed to by the Contractor and DOE.

### **2.13.2 Program Reviews**

The Contractor shall plan and conduct reviews required under this contract and shall provide agendas and document the results of the review meetings.

The Contractor shall develop a Review Plan to be included in the Project Management Plan. The Review Plan shall provide a list of proposed reviews and a description for each review. For Phase II, the Review Plan shall include, but is not limited to, the following:

- MMRTG Requirements Review
- Flight MMRTG Final Design Review

The Contractor shall prepare an agenda for each of the reviews not less than 4 weeks prior to the scheduled review. The Contractor shall provide reviewers a Review Data Package not less than two weeks prior to each design review. The Contractor shall document review results by means of minutes and an action item summary not more than 10 working days after the review. The Contractor shall maintain a tracking system for the action items until each action item is closed.

### **2.13.3 Management Meetings**

The Contractor shall participate in monthly management level project meetings held with the DOE representative at the Contractor's facility to review project status in terms of technical progress against schedule and cost performance, to review action item status, and to assign new action items for resolution as appropriate. When other reviews (e.g., quarterly reviews) coincide with monthly meetings, they shall replace monthly project meetings. These meetings shall be chaired by the Contractor's project manager or designated alternate. Contractor support personnel shall attend as required. The Contractor shall provide the agenda for each meeting to DOE for approval. The Contractor shall prepare a conference record to include action items for each of the meetings and distribute it within two weeks of each meeting. Informal technical interchange meetings will also be held as needed.

### **2.13.4 Management Information and Reporting System**

The Contractor shall maintain the management information and reporting system that shall be consistent with DOE Contractor reporting requirements provided in Attachment II. The Contractor shall provide a brief (typically less than three pages in length) weekly progress

report to DOE. Critical issues shall be identified in this report.

The Contractor shall maintain the commitments and agreements database file. These files shall include commitments and agreements with DOE, other Federal agencies, laboratories, and their contractors as necessary.

The Contractor shall maintain the engineering data file (e.g., internal project directives, project plans, travel reports, engineering memos, analyses, test reports, problem/failure reports, drawings, presentations, etc.) throughout the period of contract performance. The Contractor shall update monthly the index of the file. The Contractor shall make available specific file items to DOE on request.

The Contractor shall report on a monthly basis an assessment of work in progress. The Contractor shall measure and report on a monthly basis actual project expenditures and percent complete of work performed against the approved baseline plan using P3. In addition, a cost to complete calculation should also be reported. Actual project expenditures may be reported using software that can export cost data to P3. Reporting shall be consistent with the DOE Program Baseline Plan to an agreed-upon level of detail from the Contractor's WBS. The Contractor shall backup their current plan and forward the backed-up plan either by email or by overnight mail on portable electronic media to Orbital Sciences Corporation for integration into the DOE Program Baseline Plan.

### **2.13.5 Interface with Government Laboratories**

The Contractor shall maintain interface activities with Government laboratories and facilities concerning fuel production and processing, heat source fabrication and assembly, MMRTG fueling and testing, and transportation to the launch site. The interface with the DOE fueling and test facility shall be defined in an IWA among (1) DOE Headquarters and the cognizant field office, (2) the DOE fueling and test facility, and (3) the Contractor. The IWA shall be prepared and maintained by the Contractor, jointly agreed upon by the DOE fueling and test facility and the Contractor, and approved by DOE. The Contractor's responsibilities and authority shall be defined in this document.

This task includes project and technical support for assembly and testing of the Qualification MMRTG at the DOE fueling and test facility. The task includes review of tooling and fixture drawings, procedures, drawing change notices, discrepancy reports, inspection reports, data packages, and test reports, as well as on-site support during assembly and testing and attendance at walk-throughs, readiness reviews, and buy-off meetings. Preparation of Engineering Reports for the Qualification MMRTG is also covered under this task.

## **2.14 Quality Assurance and Reliability**

### **2.14.1 Quality Assurance**

The Contractor shall maintain the QAP developed in Phase I in accordance with the CRD, Attachment 1 of DOE Order 414.1A, "Quality Assurance," and SDPS/PQAR-1 (Revision 4), A Space and Defense Power Systems Programmatic Quality Assurance Requirements for Space and Terrestrial Nuclear Power Systems. The Contractor's QAP shall use national and international consensus standards (e.g., NQA-1, ISO 9001, etc.) in implementing quality assurance requirements. The scope, depth, and rigor of the QAP application shall be tailored by the Contractor based on the importance to safety and commensurate with contractual activities. The QAP shall include the policies and procedures for implementation of the QAP based on engineering and quality activities applicable to the specific contractual phase and shall be approved by DOE. The QAPP shall be updated, as required.

### **2.14.2 Reliability**

The Contractor shall update, as required, the Reliability Program established in Phase I. The detail of the reliability program shall be documented in a Reliability Program Plan in accordance with OSNP-3, "Reliability Program Requirements for Space and Terrestrial Nuclear Power Systems." The reliability task shall include Reliability in Design, FMECA, Failure Reporting documentation, etc., but will not include the performance of analyses and model development as required by OSNP-3, Section 4.4.

The Reliability Program Plan shall delineate the Contractor's methodology for planning, establishing, implementing, documenting, and maintaining control of a formal reliability program that will result in reliable mission performance with appropriate documentation. The plan shall demonstrate compliance with the requirements of those sections of OSNP-3 that will be performed during phases of the project.

The Contractor shall update, as required, the system FMECA, evaluate all test results in support of the FMECA for the system, address the impact of test results on the FMECA for the system, and identify all credible SPFs. All SPFs must be documented and approved by DOE.

The Contractor shall establish a closed-loop failure and corrective action system. Each failure shall be documented as required by OSNP-3. All failures shall be reported to DOE and discussed as part of the monthly progress reports. The Contractor shall list root cause and recommendations for corrective action to prevent recurrence of the failure, if applicable, as explained in OSNP-3.

### **2.14.3 Operations Analysis Support**

The Contractor shall support a programmatic Operations Analysis (OA). This OA will be a formal review conducted by DOE of the operations with emphasis on safety, safeguards assurance and investment protection. All operations in the “factory-to-flight” sequence involving nuclear fuel, heat sources, and MMRTGs shall be analyzed. The Contractor shall participate as a member of the OA team.

### **2.15 Resident Representative at Contractor Facilities**

The Contractor shall supply office facilities and services to accommodate two DOE on-site representatives. Facilities are to include offices, desks, personal computers with email and Internet capabilities, tables, file cabinets, phones with voicemail, and copying and fax services. The Contractor shall provide unescorted badge privileges for the on-site representative(s) for access to all project activity areas.

## **PHASE III (OPTION)**

### **3.0 FLIGHT MMRTG PROGRAM**

In the Phase III Option, the Contractor shall conduct system integration activities and fabricate, assemble, and acceptance test two (2) Flight ETGs for the Mars Mobile Science Laboratory mission in 2009 (Mars 09). The Contractor shall support the fueling and acceptance testing activities at the DOE fueling and test facility. In addition, the Contractor shall conduct safety analyses, prepare safety documentation, support the NASA EIS and interagency launch approval processes, and provide launch support.

#### **3.1 System Integration (Mars 09)**

The Contractor shall continue to conduct system integration activities for all technical aspects of the project, including interfacing with NASA, launch vehicle supplier, DOE laboratories, launch site operations, and others as necessary. The Contractor shall prepare for and attend interface meetings required to perform the system integration activities, including participation as required at NASA review meetings. The Contractor shall prepare and implement, or assist DOE in preparing and implementing, interface working agreements with NASA, DOE laboratories, and others.

#### **3.2 Mission Requirements Review**

The Contractor shall evaluate the NASA mission requirements to verify that the qualification of the MMRTG is not compromised. The Contractor shall conduct a formal requirements review. The review shall address the manner in which the MMRTG design satisfies the NASA mission requirements.

#### **3.3 Thermoelectric Components Fabrication**

The Contractor shall demonstrate that the thermoelectric component fabrication process continues to uniformly and reliably produce qualified thermoelectric components. If requested, the Contractor shall conduct a readiness review before proceeding to fabrication. This review shall include procedures, personnel qualification, personnel certification and facilities readiness. With DOE's approval, the Contractor shall proceed to produce thermoelectric components for the Flight ETGs.

The Contractor shall continue testing the thermoelectric components that were initiated in previous phase(s) to further determine their lifetime performance. The Contractor shall prepare and issue a report on the performance of the thermoelectric components.

### **3.4 Assembled Flight ETG**

The Contractor shall fabricate and assemble two Flight ETGs. Vendors shall be identified and qualified for procured components and materials. The Contractor shall train and qualify personnel to fabricate and assemble the Flight ETGs. The Contractor shall identify critical components and, if warranted, provide spares of these components to provide for quick repair or replacement. If requested, a fabrication readiness review shall be conducted before proceeding to fabrication. The readiness review shall include procedures, personnel qualifications and certification, and facilities. DOE approval is required before fabrication is initiated.

### **3.5 Flight ETG Acceptance Tests**

The Contractor shall conduct acceptance tests to demonstrate the Flight ETGs meet the Flight ETG Product Specification. The Flight ETG Acceptance Test Plan shall be prepared by the Contractor and approved by DOE. The Flight ETG Acceptance Test Plan shall provide detailed testing requirements and identify pass/fail criteria for each test.

The Contractor shall prepare a Flight ETG Test Report for each Flight ETG. The Flight ETG Test Report shall be a stand-alone document encompassing the Flight ETG Acceptance Test Plan, testing history, and test results. The report shall provide objective evidence that the Flight ETG meets the Flight ETG Product Specification.

The Contractor shall prepare a data package for each Flight ETG. The data packages shall be submitted to DOE for review and approval. The Contractor shall ship the Flight ETGs to the DOE fueling and test facility.

### **3.6 Fueling and Acceptance Testing Support at the DOE Fueling and Test Facility**

The Contractor shall update the test plans and detailed handling, processing, fueling, and acceptance test specifications for the DOE fueling and test facility to enable development of corresponding procedures. The DOE fueling and test facility personnel will provide input to the Contractor for these specifications. Fueling and acceptance testing procedures will be prepared by the DOE fueling and test facility, reviewed by the Contractor, and approved by DOE.

The Contractor shall support the fueling and testing of the Flight MMRTGs at the DOE fueling and test facility. The Contractor shall provide oversight of the fueling and testing operations (e.g., procedure review, tooling and fixture review, walkthroughs, readiness reviews, etc.).

The Contractor shall prepare a Summary Flight MMRTG Test Report. The Summary Flight

MMRTG Test Report shall be a stand-alone document encompassing the test plan, testing history, and test results. The report shall provide objective evidence that the Flight MMRTG meets the Flight MMRTG Product Specification.

### **3.7 Life-Testing and Performance Model Verification**

The Contractor shall continue monitoring, analyzing, and reporting the results of the thermoelectric component life-testing and Qualification MMRTG life-testing tasks. The Contractor shall issue results of the lifetime model predictions and performance of the thermoelectric components and the MMRTG. The information reported should include, but is not limited to, performance, anomalies, analysis of test results, performance predictions and model validation results.

### **3.8 Launch Support**

The Contractor shall provide ground operations planning support, participate in launch working groups and provide representation at meetings concerning MMRTG needs and characteristics for the purpose of planning for delivery, storage, performance of fit-checks, spacecraft installation, launch and close-out operations. This includes supporting shipping and launch readiness reviews. For planning purposes, the site for the potential Mars 09 mission launch will be KSC/CCAFS. Support shall include providing necessary personnel, attendance at meetings, and home office technical support.

The Contractor shall provide technical support to the DOE fueling and test facility for the monitoring of the Flight MMRTGs at the launch site, as required.

### **3.9 NEPA and Launch Safety**

The Contractor shall, in support of the launch approval process for the potential 2009 mission, continue performing safety analyses of the overall response of the MMRTG to accidents that could occur after attachment of the MMRTG to the Mars 09 spacecraft, in the pre-launch period or during the launch through Earth escape. This shall include preparation of final safety analysis reports and participation in the interagency launch approval process.

The Contractor shall continue to support and participate in any NASA NEPA activities that have not been brought to closure. During Phase III, it is anticipated that the focus of the analysis will be in support of the launch approval safety analysis activities. Also during Phase III, the Contractor shall support any databook activities that remain open. The Contractor shall participate in meetings with DOE in development of these analyses.

The Contractor shall issue the Draft Safety Analysis Report (DSAR) and the FSAR for the Mars 09 mission. The Contractor shall support the review of such documentation by the

INSRP and other appropriate reviewers as indicated by DOE. This includes providing assistance to INSRP in conducting their investigations and review.

After completion of launch activities, the Contractor shall submit to DOE a report containing a functional description of the computer codes used in their risk assessments, an executable copy of their computer codes, installation of the codes at a facility identified by DOE, and provide limited training in the operation of those codes.

The Contractor shall update the Safety Test Plan developed in previous phase(s). The Contractor shall continue to provide support in the planning of the overall MMRTG safety test program. The Contractor shall provide support for the actual testing and analysis of test results. The testing may evaluate the generator design, hardware, and interactions with the GPHS modules at the system level under various accident environments.

The Contractor shall provide safety test hardware consistent with the Safety Test Plan. The hardware shall be representative of the MMRTG hardware and consist of all elements that could affect the response of the GPHS modules and fueled clads to accident environments.

### **3.10 Special Studies**

This task consists of the design and analysis activities required to perform applicable studies for DOE. The Contractor shall produce drawings, requirements, and specification documents to support these studies. Specific areas of required technical refinement shall be identified by the Contractor, including such areas as safety, efficiency, fabrication and testing, analysis of flight data, and performance and design improvements. The Contractor shall also define test requirements, review test plans, conduct tests, and analyze test data as applicable to qualify the proposed refinements or improvements. Those areas or items specifically approved by the DOE shall be studied and necessary experiments conducted to assess feasibility and payoff for the application. The specific applications and user contacts will be identified by DOE. An effort not to exceed three (3) man-years per year of engineering staff time plus travel is anticipated for this task.

### **3.11 Project Management**

The Contractor shall provide for the overall management of the effort. The Contractor shall implement a tailored project management system to set forth the principles and requirements that govern the development, approval, and execution of the contractual effort in accordance with DOE Order 4700.1 "Project Management System."

#### **3.11.1 Project Management Plan**

The Contractor shall update, as appropriate, the Project Management Plan, WBS, and the baseline plan. The Contractor shall measure monthly performance against the DOE

approved baseline plan using P3.

OSC, DOE's designated contractor, will develop a Program Baseline Plan that will incorporate input from all program participants. In updating the baseline plan for this contract, the Contractor shall coordinate the structure of their baseline plan with OSC so that the Contractor's baseline plan can be integrated into the Program Baseline Plan. The level of detail to be included and reported to in the Program Baseline Plan shall be agreed to by the Contractor and DOE.

### **3.11.2 Program Design Reviews**

The Contractor shall plan and conduct reviews required under this contract and shall provide agendas and document the results of the review meetings.

The Contractor shall develop a Review Plan to be included in the Project Management Plan. The Review Plan shall provide a list of proposed reviews and a description for each review. For Phase III, the Review Plan shall include, but is not limited to, the following:

- Mission Requirements Review
- Buy Off Review
- Shipment Readiness Review

The Contractor shall prepare an agenda for each of the reviews not less than 4 weeks prior to the scheduled review. The Contractor shall provide reviewers a Review Data Package not less than two weeks prior to each design review. The Contractor shall document review results by means of minutes and action item summary not more than 10 working days after the review. The Contractor shall maintain a tracking system for the action items until each action item is closed.

### **3.11.3 Management Meetings**

The Contractor shall participate in monthly management level project meetings held with the DOE representative at the Contractor's facility to review project status in terms of technical progress against schedule and cost performance, to review action item status, and to assign new action items for resolution as appropriate. When other reviews (e.g., quarterly reviews) coincide with monthly meetings, they shall replace monthly project meetings. These meetings shall be chaired by the Contractor's project manager or designated alternate. Contractor support personnel shall attend as required. The Contractor shall provide the agenda for each meeting to DOE for approval. The Contractor shall prepare a conference record to include action items for each of the meetings and distribute it within two weeks of each meeting. Informal technical interchange meetings will also be held as needed.

### **3.11.4 Management Information and Reporting System**

The Contractor shall maintain the management information and reporting system that shall be consistent with DOE Contractor reporting requirements provided in Attachment II. The Contractor shall provide a brief (typically less than three pages in length) weekly progress report to DOE. Critical issues shall be identified in this report.

The Contractor shall maintain the commitments and agreements database file. These files shall include commitments and agreements with DOE, other Federal agencies, laboratories, and their contractors as necessary.

The Contractor shall maintain the engineering data file (e.g., internal project directives, project plans, travel reports, engineering memos, analyses, test reports, problem/failure reports, drawings, presentations, etc.) throughout the period of contract performance. The Contractor shall update monthly the index of the file. The Contractor shall make available specific file items to DOE on request.

The Contractor shall report on a monthly basis an assessment of work in progress. The Contractor shall measure and report on a monthly basis actual project expenditures and percent complete of work performed against the approved baseline plan using P3. In addition, a cost to complete calculation should also be reported. Actual project expenditures may be reported using software that can export cost data to P3. Reporting shall be consistent with the DOE Program Baseline Plan to an agreed-upon level of detail from the Contractor's WBS. The Contractor shall backup their current plan and forward the backed-up plan either by email or by overnight mail on portable electronic media to Orbital Sciences Corporation for integration into the DOE Program Baseline Plan.

### **3.11.5 Interface with Government Laboratories**

The Contractor shall maintain interface activities with Government laboratories and facilities concerning fuel production and processing, heat source fabrication and assembly, MMRTG fueling and testing, and transportation to the launch site. The interface with the DOE fueling and test facility shall be defined in an IWA among (1) DOE Headquarters and the cognizant field office, (2) the DOE fueling and test facility, and (3) the Contractor. The IWA shall be prepared and maintained by the Contractor, jointly agreed upon by the DOE fueling and test facility and the Contractor, and approved by DOE. The Contractor's responsibilities and authority shall be defined in this document.

## **3.12 Quality Assurance and Reliability**

### **3.12.1 Quality Assurance**

The Contractor shall maintain the QAP in accordance with the CRD, Attachment 1 of DOE

Order 414.1A, Quality Assurance, and SDPS/PQAR-1 (Revision 4), A Space and Defense Power Systems Programmatic Quality Assurance Requirements for Space and Terrestrial Nuclear Power Systems. The Contractor's QAP shall use national and international consensus standards (e.g., NQA-1, ISO 9001, etc.) in implementing quality assurance requirements. The scope, depth, and rigor of the QAP application shall be tailored by the Contractor based on the importance to safety and commensurate with contractual activities. The QAP shall include the policies and procedures for implementation of the QAP based on engineering and quality activities applicable to the specific contractual phase and shall be provided to DOE. The QAPP shall be updated, as required.

### **3.12.2 Reliability**

The Contractor shall update, as required, the Reliability Program. The detail of the reliability program shall be documented in a Reliability Program Plan in accordance with OSNP-3, "Reliability Program Requirements for Space and Terrestrial Nuclear Power Systems." The reliability task shall include Reliability in Design, FMECA, Failure Reporting documentation, etc., but will not include the performance of analyses and model development as required by OSNP-3, Section 4.4.

The Reliability Program Plan shall delineate the Contractor's methodology for planning, establishing, implementing, documenting, and maintaining control of a formal reliability program that will result in reliable mission performance with appropriate documentation. The plan shall demonstrate compliance with the requirements of those sections of OSNP-3 that will be performed during phases of the project.

The Contractor shall update, as required, the system FMECA, evaluate all test results in support of the FMECA for the system, address the impact of test results on the FMECA for the system, and identify all credible SPFs. All SPFs must be documented and approved by DOE.

The Contractor shall establish a closed-loop failure and corrective action system. Each failure shall be documented as required by OSNP-3. All failures shall be reported to DOE and discussed as part of the monthly progress reports. The Contractor shall list root cause and recommendations for corrective action to prevent recurrence of the failure, if applicable, as explained in OSNP-3.

### **3.12.3 Operations Analysis**

The Contractor shall support a programmatic OA. This OA will be a formal review conducted by DOE of the operations with emphasis on safety, safeguards assurance and investment protection. All operations in the "factory-to-flight" sequence involving nuclear fuel, heat sources, and MMRTGs shall be analyzed. The Contractor shall participate as a member of the OA team.

### **3.13 Resident Representative at Contractor Facilities**

The Contractor shall supply office facilities and services to accommodate two DOE on-site representative. Facilities are to include offices, desks, personal computers with email and Internet capabilities, tables, file cabinets, phone with voicemail, and copying and fax services. The Contractor shall provide unescorted badge privileges for the on-site representative(s) for access to all project activity areas.

## **PHASE IV (OPTION)**

### **4.0 FLIGHT MMRTG PROGRAM**

In the Phase IV Option, the Contractor shall conduct system integration activities and fabricate, assemble, and acceptance test three (3) Flight ETGs for the Outer Planet mission in 2011. The Contractor shall support the fueling and acceptance testing activities at the DOE fueling and test facility. In addition, the Contractor shall conduct safety analyses, prepare safety documentation, support the NASA EIS and interagency launch approval processes, and provide launch support.

#### **4.1 System Integration (Outer Planet 11)**

The Contractor shall continue to conduct system integration activities for all technical aspects of the project, including interfacing with NASA, launch vehicle supplier, DOE laboratories, launch site operations, and others as necessary. The Contractor shall prepare for and attend interface meetings required to perform the system integration activities, including participation as required at NASA review meetings. The Contractor shall prepare and implement, or assist DOE in preparing and implementing, interface working agreements with NASA, DOE laboratories, and others.

#### **4.2 Mission Requirements Review**

The Contractor shall evaluate the NASA mission requirements to verify that the qualification of the MMRTG is not compromised. The Contractor shall conduct a formal requirements review. The review shall address the manner in which the MMRTG design satisfies the NASA mission requirements.

#### **4.3 Thermoelectric Components Fabrication**

The Contractor shall demonstrate that the thermoelectric component fabrication process continues to uniformly and reliably produce qualified thermoelectric components. If requested, the Contractor shall conduct a readiness review before proceeding to fabrication. This review shall include procedures, personnel qualification, personnel certification and facilities readiness. With DOE's approval, the Contractor shall proceed to produce thermoelectric components for the Flight ETGs.

The Contractor shall continue testing the thermoelectric components that were initiated in previous phase(s) to further determine their lifetime performance. The Contractor shall prepare and issue a report on the performance of the thermoelectric components.

#### **4.4 Assembled Flight ETG**

The Contractor shall fabricate and assemble three Flight ETGs. Vendors shall be identified and qualified for procured components and materials. The Contractor shall train and qualify personnel to fabricate and assemble the Flight ETGs. The Contractor shall identify critical components and, if warranted, provide spares of these components to provide for quick repair or replacement. If requested, a fabrication readiness review shall be conducted before proceeding to fabrication. The readiness review shall include procedures, personnel qualifications and certification, and facilities. DOE approval is required before fabrication is initiated.

#### **4.5 Flight ETG Acceptance Tests**

The Contractor shall conduct acceptance tests to demonstrate the Flight ETGs meet the Flight ETG Product Specification. The Flight ETG Acceptance Test Plan shall be prepared by the Contractor and approved by DOE. The Flight ETG Acceptance Test Plan shall provide detailed testing requirements and identify pass/fail criteria for each test.

The Contractor shall prepare a Flight ETG Test Report for each Flight ETG. The Flight ETG Test Report shall be a stand-alone document encompassing the Flight ETG Acceptance Test Plan, testing history, and test results. The report shall provide objective evidence that the Flight ETG meets the Flight ETG Product Specification.

The Contractor shall prepare a data package for each Flight ETG. The data packages shall be submitted to DOE for review and approval. The Contractor shall ship the Flight ETGs to the DOE fueling and test facility.

#### **4.6 Fueling and Acceptance Testing Support at the DOE Fueling and Test Facility**

The Contractor shall update the test plans and detailed handling, processing, fueling, and acceptance test specifications for the DOE fueling and test facility to enable development of corresponding procedures. The DOE fueling and test facility personnel will provide input to the Contractor for these specifications. Fueling and acceptance testing procedures will be prepared by the DOE fueling and test facility, reviewed by the Contractor, and approved by DOE.

The Contractor shall support the fueling and testing of the Flight MMRTGs at the DOE fueling and test facility. The Contractor shall provide oversight of the fueling and testing operations (e.g., procedure review, tooling and fixture review, walkthroughs, readiness reviews, etc.).

The Contractor shall prepare a Summary Flight MMRTG Test Report. The Summary Flight

MMRTG Test Report shall be a stand-alone document encompassing the test plan, testing history, and test results. The report shall provide objective evidence that the Flight MMRTG meets the Flight MMRTG Product Specification.

#### **4.7 Life-Testing and Performance Model Verification**

The Contractor shall continue monitoring, analyzing, and reporting the results of the thermoelectric component life-testing and Qualification MMRTG life-testing tasks. The Contractor shall issue results of the lifetime model predictions and performance of the thermoelectric components and the MMRTG. The information reported should include, but is not limited to, performance, anomalies, analysis of test results, performance predictions and model validation results.

#### **4.8 Launch Support**

The Contractor shall provide ground operations planning support, participate in launch working groups and provide representation at meetings concerning MMRTG needs and characteristics for the purpose of planning for delivery, storage, performance of fit-checks, spacecraft installation, launch and close-out operations. This includes supporting shipping and launch readiness reviews. For planning purposes, the site for the potential Outer Planet 11 mission launch will be KSC/CCAFS. Support shall include providing necessary personnel, attendance at meetings, and home office technical support.

The Contractor shall provide technical support to the DOE fueling and test facility for the monitoring of the Flight MMRTGs at the launch site, as required.

#### **4.9 NEPA and Launch Safety**

The Contractor shall, in support of the launch approval process for the potential 2011 mission, continue performing safety analyses of the overall response of the MMRTG to accidents that could occur after attachment of the MMRTG to the Outer Planet 11 spacecraft, in the pre-launch period or during the launch through Earth escape. This shall include preparation of final safety analysis reports and participation in the interagency launch approval process.

The Contractor shall continue to support and participate in any NASA NEPA activities that have not been brought to closure. During Phase IV, it is anticipated that the focus of the analysis will be in support of the launch approval safety analysis activities. Also during Phase IV, the Contractor shall support any databook activities that remain open. The Contractor shall participate in meetings with DOE in development of these analyses.

The Contractor shall issue the DSAR and the FSAR for the Outer Planet 11 mission. The Contractor shall support the review of such documentation by the INSRP and other

appropriate reviewers as indicated by DOE. This includes providing assistance to INSRP in conducting their investigations and review.

After completion of launch activities, the Contractor shall submit to DOE a report containing a functional description of the computer codes used in their risk assessments, an executable copy of their computer codes, installation of the codes at a facility identified by DOE, and provide limited training in the operation of those codes.

The Contractor shall update the Safety Test Plan developed in previous phase(s). The Contractor shall continue to provide support in the planning of the overall MMRTG safety test program. The Contractor shall provide support for the actual testing and analysis of test results. The testing may evaluate the generator design, hardware, and interactions with the GPHS modules at the system level under various accident environments.

The Contractor shall provide safety test hardware consistent with the Safety Test Plan. The hardware shall be representative of the MMRTG hardware and consist of all elements that could affect the response of the GPHS modules and fueled clads to accident environments.

#### **4.10 Special Studies**

This task consists of the design and analysis activities required to perform applicable studies for DOE. The Contractor shall produce drawings, requirements, and specification documents to support these studies. Specific areas of required technical refinement shall be identified by the Contractor, including such areas as safety, efficiency, fabrication and testing, analysis of flight data, and performance and design improvements. The Contractor shall also define test requirements, review test plans, conduct tests, and analyze test data as applicable to qualify the proposed refinements or improvements. Those areas or items specifically approved by the DOE shall be studied and necessary experiments conducted to assess feasibility and payoff for the application. The specific applications and user contacts will be identified by DOE. An effort not to exceed three (3) man-years per year of engineering staff time plus travel is anticipated for this task.

#### **4.11 Project Management**

The Contractor shall provide for the overall management of the effort. The Contractor shall implement a tailored project management system to set forth the principles and requirements that govern the development, approval, and execution of the contractual effort in accordance with DOE Order 4700.1 "Project Management System."

##### **4.11.1 Project Management Plan**

The Contractor shall update, as appropriate, the Project Management Plan, WBS, and the baseline plan. The Contractor shall measure monthly performance against the DOE

approved baseline plan using P3.

OSC, DOE's designated contractor, will develop a Program Baseline Plan that will incorporate input from all program participants. In updating the baseline plan for this contract, the Contractor shall coordinate the structure of their baseline plan with OSC so that the Contractor's baseline plan can be integrated into the Program Baseline Plan. The level of detail to be included and reported to in the Program Baseline Plan shall be agreed to by the Contractor and DOE.

#### **4.11.2 Program Design Reviews**

The Contractor shall plan and conduct reviews required under this contract and shall provide agendas and document the results of the review meetings.

The Contractor shall develop a Review Plan to be included in the Project Management Plan. The Review Plan shall provide a list of proposed reviews and a description for each review. For Phase IV, the Review Plan shall include, but is not limited to, the following:

- Mission Requirements Review
- Buy Off Review
- Shipment Readiness Review

The Contractor shall prepare an agenda for each of the reviews not less than 4 weeks prior to the scheduled review. The Contractor shall provide reviewers a Review Data Package not less than two weeks prior to each design review. The Contractor shall document review results by means of minutes and action item summary not more than 10 working days after the review. The Contractor shall maintain a tracking system for the action items until each action item is closed.

#### **4.11.3 Management Meetings**

The Contractor shall participate in monthly management level project meetings held with the DOE representative at the Contractor's facility to review project status in terms of technical progress against schedule and cost performance, to review action item status, and to assign new action items for resolution as appropriate. When other reviews (e.g., quarterly reviews) coincide with monthly meetings, they shall replace monthly project meetings. These meetings shall be chaired by the Contractor's project manager or designated alternate. Contractor support personnel shall attend as required. The Contractor shall provide the agenda for each meeting to DOE for approval. The Contractor shall prepare a conference record to include action items for each of the meetings and distribute it within two weeks of each meeting. Informal technical interchange meetings will also be held as needed.

#### **4.11.4 Management Information and Reporting System**

The Contractor shall maintain the management information and reporting system that shall be consistent with DOE Contractor reporting requirements provided in Attachment II. The Contractor shall provide a brief (typically less than three pages in length) weekly progress report to DOE. Critical issues shall be identified in this report.

The Contractor shall maintain the commitments and agreements database file. These files shall include commitments and agreements with DOE, other Federal agencies, laboratories, and their contractors as necessary.

The Contractor shall maintain the engineering data file (e.g., internal project directives, project plans, travel reports, engineering memos, analyses, test reports, problem/failure reports, drawings, presentations, etc.) throughout the period of contract performance. The Contractor shall update monthly the index of the file. The Contractor shall make available specific file items to DOE on request.

The Contractor shall report on a monthly basis an assessment of work in progress. The Contractor shall measure and report on a monthly basis actual project expenditures and percent complete of work performed against the approved baseline plan using P3. In addition, a cost to complete calculation should also be reported. Actual project expenditures may be reported using software that can export cost data to P3. Reporting shall be consistent with the DOE Program Baseline Plan to an agreed-upon level of detail from the Contractor's WBS. The Contractor shall backup their current plan and forward the backed-up plan either by email or by overnight mail on portable electronic media to Orbital Sciences Corporation for integration into the DOE Program Baseline Plan.

#### **4.11.5 Interface with Government Laboratories**

The Contractor shall maintain interface activities with Government laboratories and facilities concerning fuel production and processing, heat source fabrication and assembly, MMRTG fueling and testing, and transportation to the launch site. The interface with the DOE fueling and test facility shall be defined in an IWA among (1) DOE Headquarters and the cognizant field office, (2) the DOE fueling and test facility, and (3) the Contractor. The IWA shall be prepared and maintained by the Contractor, jointly agreed upon by the DOE fueling and test facility and the Contractor, and approved by DOE. The Contractor's responsibilities and authority shall be defined in this document.

### **4.12 Quality Assurance and Reliability**

#### **4.12.1 Quality Assurance**

The Contractor shall maintain the QAP in accordance with the CRD, Attachment 1 of DOE

Order 414.1A, Quality Assurance, and SDPS/PQAR-1 (Revision 4), A Space and Defense Power Systems Programmatic Quality Assurance Requirements for Space and Terrestrial Nuclear Power Systems. The Contractor's QAP shall use national and international consensus standards (e.g., NQA-1, ISO 9001, etc.) in implementing quality assurance requirements. The scope, depth, and rigor of the QAP application shall be tailored by the Contractor based on the importance to safety and commensurate with contractual activities. The QAP shall include the policies and procedures for implementation of the QAP based on engineering and quality activities applicable to the specific contractual phase and shall be provided to DOE. The QAPP shall be updated, as required.

#### **4.12.2 Reliability**

The Contractor shall update, as required, the Reliability Program. The detail of the reliability program shall be documented in a Reliability Program Plan in accordance with OSNP-3, "Reliability Program Requirements for Space and Terrestrial Nuclear Power Systems." The reliability task shall include Reliability in Design, FMECA, Failure Reporting documentation, etc., but will not include the performance of analyses and model development as required by OSNP-3, Section 4.4.

The Reliability Program Plan shall delineate the Contractor's methodology for planning, establishing, implementing, documenting, and maintaining control of a formal reliability program that will result in reliable mission performance with appropriate documentation. The plan shall demonstrate compliance with the requirements of those sections of OSNP-3 that will be performed during phases of the project.

The Contractor shall update, as required, the system FMECA, evaluate all test results in support of the FMECA for the system, address the impact of test results on the FMECA for the system, and identify all credible SPFs. All SPFs must be documented and approved by DOE.

The Contractor shall establish a closed-loop failure and corrective action system. Each failure shall be documented as required by OSNP-3. All failures shall be reported to DOE and discussed as part of the monthly progress reports. The Contractor shall list root cause and recommendations for corrective action to prevent recurrence of the failure, if applicable, as explained in OSNP-3.

#### **4.12.3 Operations Analysis**

The Contractor shall support a programmatic OA. This OA will be a formal review conducted by DOE of the operations with emphasis on safety, safeguards assurance and investment protection. All operations in the "factory-to-flight" sequence involving nuclear fuel, heat sources, and MMRTGs shall be analyzed. The Contractor shall participate as a member of the OA team.

#### **4.13 Resident Representative at Contractor Facilities**

The Contractor shall supply office facilities and services to accommodate two DOE on-site representative. Facilities are to include offices, desks, personal computers with email and Internet capabilities, tables, file cabinets, phone with voicemail, and copying and fax services. The Contractor shall provide unescorted badge privileges for the on-site representative(s) for access to all project activity areas.

## **PHASE V (OPTION)**

### **5.0 FLIGHT MMRTG PROGRAM**

In the Phase V Option, the Contractor shall conduct system integration activities and fabricate, assemble, and acceptance test two (2) Flight ETGs for the Mars Sample Return Mission in 2013 (Mars 13). The Contractor shall support the fueling and acceptance testing activities at the DOE fueling and test facility. In addition, the Contractor shall conduct safety analyses, prepare safety documentation, support the NASA EIS and interagency launch approval processes, and provide launch support.

#### **5.1 System Integration (Mars 13)**

The Contractor shall continue to conduct system integration activities for all technical aspects of the project, including interfacing with NASA, launch vehicle supplier, DOE laboratories, launch site operations, and others as necessary. The Contractor shall prepare for and attend interface meetings required to perform the system integration activities, including participation as required at NASA review meetings. The Contractor shall prepare and implement, or assist DOE in preparing and implementing, interface working agreements with NASA, DOE laboratories, and others.

#### **5.2 Mission Requirements Review**

The Contractor shall evaluate the NASA mission requirements to verify that the qualification of the MMRTG is not compromised. The Contractor shall conduct a formal requirements review. The review shall address the manner in which the MMRTG design satisfies the NASA mission requirements.

#### **5.3 Thermoelectric Components Fabrication**

The Contractor shall demonstrate that the thermoelectric component fabrication process continues to uniformly and reliably produce qualified thermoelectric components. If requested, the Contractor shall conduct a readiness review before proceeding to fabrication. This review shall include procedures, personnel qualification, personnel certification and facilities readiness. With DOE's approval, the Contractor shall proceed to produce thermoelectric components for the Flight ETGs.

The Contractor shall continue testing the thermoelectric components that were initiated in previous phase(s) to further determine their lifetime performance. The Contractor shall prepare and issue a report on the performance of the thermoelectric components.

#### **5.4 Assembled Flight ETG**

The Contractor shall fabricate and assemble two Flight ETGs. Vendors shall be identified and qualified for procured components and materials. The Contractor shall train and qualify personnel to fabricate and assemble the Flight ETGs. The Contractor shall identify critical components and, if warranted, provide spares of these components to provide for quick repair or replacement. If requested, a fabrication readiness review shall be conducted before proceeding to fabrication. The readiness review shall include procedures, personnel qualifications and certification, and facilities. DOE approval is required before fabrication is initiated.

#### **5.5 Flight ETG Acceptance Tests**

The Contractor shall conduct acceptance tests to demonstrate the Flight ETGs meet the Flight ETG Product Specification. The Flight ETG Acceptance Test Plan shall be prepared by the Contractor and approved by DOE. The Flight ETG Acceptance Test Plan shall provide detailed testing requirements and identify pass/fail criteria for each test.

The Contractor shall prepare a Flight ETG Test Report for each Flight ETG. The Flight ETG Test Report shall be a stand-alone document encompassing the Flight ETG Acceptance Test Plan, testing history, and test results. The report shall provide objective evidence that the Flight ETG meets the Flight ETG Product Specification.

The Contractor shall prepare a data package for each Flight ETG. The data packages shall be submitted to DOE for review and approval. The Contractor shall ship the Flight ETGs to the DOE fueling and test facility.

#### **5.6 Fueling and Acceptance Testing Support at the DOE Fueling and Test Facility**

The Contractor shall update the test plans and detailed handling, processing, fueling, and acceptance test specifications for the DOE fueling and test facility to enable development of corresponding procedures. The DOE fueling and test facility personnel will provide input to the Contractor for these specifications. Fueling and acceptance testing procedures will be prepared by the DOE fueling and test facility, reviewed by the Contractor, and approved by DOE.

The Contractor shall support the fueling and testing of the Flight MMRTGs at the DOE fueling and test facility. The Contractor shall provide oversight of the fueling and testing operations (e.g., procedure review, tooling and fixture review, walkthroughs, readiness reviews, etc.).

The Contractor shall prepare a Summary Flight MMRTG Test Report. The Summary Flight

MMRTG Test Report shall be a stand-alone document encompassing the test plan, testing history, and test results. The report shall provide objective evidence that the Flight MMRTG meets the Flight MMRTG Product Specification.

### **5.7 Life-Testing and Performance Model Verification**

The Contractor shall continue monitoring, analyzing, and reporting the results of the thermoelectric component life-testing and Qualification MMRTG life-testing tasks. The Contractor shall issue results of the lifetime model predictions and performance of the thermoelectric components and the MMRTG. The information reported should include, but is not limited to, performance, anomalies, analysis of test results, performance predictions and model validation results.

### **5.8 Launch Support**

The Contractor shall provide ground operations planning support, participate in launch facility working groups and provide representation at meetings concerning MMRTG needs and characteristics for the purpose of planning for delivery, storage, performance of fit-checks, spacecraft installation, launch and close-out operations. This includes supporting shipping and launch readiness reviews. For planning purposes, the site for the potential Mars 13 mission launch will be KSC/CCAFS. Support shall include providing necessary personnel, attendance at meetings, and home office technical support.

The Contractor shall provide technical support to the DOE fueling and test facility for the monitoring of the Flight MMRTGs at the launch site, as required.

### **5.9 NEPA and Launch Safety**

The Contractor shall, in support of the launch approval process for the potential 2013 mission, continue performing safety analyses of the overall response of the MMRTG to accidents that could occur after attachment of the MMRTG to the Mars 13 spacecraft, in the pre-launch period or during the launch through Earth escape. This shall include preparation of final safety analysis reports and participation in the interagency launch approval process.

The Contractor shall continue to support and participate in any NASA NEPA activities that have not been brought to closure. During Phase V, it is anticipated that the focus of the analysis will be in support of the launch approval safety analysis activities. Also during Phase V, the Contractor shall support any databook activities that remain open. The Contractor shall participate in meetings with DOE in development of these analyses.

The Contractor shall issue the DSAR and the FSAR for the Mars 13 mission. The Contractor shall support the review of such documentation by the INSRP and other

appropriate reviewers as indicated by DOE. This includes providing assistance to INSRP in conducting their investigations and review.

After completion of launch activities, the Contractor shall submit to DOE a report containing a functional description of the computer codes used in their risk assessments, an executable copy of their computer codes, installation of the codes at a facility identified by DOE, and provide limited training in the operation of those codes.

The Contractor shall update the Safety Test Plan developed in previous phase(s). The Contractor shall continue to provide support in the planning of the overall MMRTG safety test program. The Contractor shall provide support for the actual testing and analysis of test results. The testing may evaluate the generator design, hardware, and interactions with the GPHS modules at the system level under various accident environments.

The Contractor shall provide safety test hardware consistent with the Safety Test Plan. The hardware shall be representative of the MMRTG hardware and consist of all elements that could affect the response of the GPHS modules and fueled clads to accident environments.

### **5.10 Special Studies**

This task consists of the design and analysis activities required to perform applicable studies for DOE. The Contractor shall produce drawings, requirements, and specification documents to support these studies. Specific areas of required technical refinement shall be identified by the Contractor, including such areas as safety, efficiency, fabrication and testing, analysis of flight data, and performance and design improvements. The Contractor shall also define test requirements, review test plans, conduct tests, and analyze test data as applicable to qualify the proposed refinements or improvements. Those areas or items specifically approved by the DOE shall be studied and necessary experiments conducted to assess feasibility and payoff for the application. The specific applications and user contacts will be identified by DOE. An effort not to exceed three (3) man-years per year of engineering staff time plus travel is anticipated for this task.

### **5.11 Project Management**

The Contractor shall provide for the overall management of the effort. The Contractor shall implement a tailored project management system to set forth the principles and requirements that govern the development, approval, and execution of the contractual effort in accordance with DOE Order 4700.1 "Project Management System."

#### **5.11.1 Project Management Plan**

The Contractor shall update, as appropriate, the Project Management Plan, WBS, and the baseline plan. The Contractor shall measure monthly performance against the DOE

approved baseline plan using P3.

OSC, DOE's designated contractor, will develop a Program Baseline Plan that will incorporate input from all program participants. In updating the baseline plan for this contract, the Contractor shall coordinate the structure of their baseline plan with OSC so that the Contractor's baseline plan can be integrated into the Program Baseline Plan. The level of detail to be included and reported to in the Program Baseline Plan shall be agreed to by the Contractor and DOE.

### **5.11.2 Program Design Reviews**

The Contractor shall plan and conduct reviews required under this contract and shall provide agendas and document the results of the review meetings.

The Contractor shall develop a Review Plan to be included in the Project Management Plan. The Review Plan shall provide a list of proposed reviews and a description for each review. For Phase V, the Review Plan shall include, but is not limited to, the following:

- Mission Requirements Review
- Buy Off Review
- Shipment Readiness Review

The Contractor shall prepare an agenda for each of the reviews not less than 4 weeks prior to the scheduled review. The Contractor shall provide reviewers a Review Data Package not less than two weeks prior to each design review. The Contractor shall document review results by means of minutes and action item summary not more than 10 working days after the review. The Contractor shall maintain a tracking system for the action items until each action item is closed.

### **5.11.3 Management Meetings**

The Contractor shall participate in monthly management level project meetings held with the DOE representative at the Contractor's facility to review project status in terms of technical progress against schedule and cost performance, to review action item status, and to assign new action items for resolution as appropriate. When other reviews (e.g., quarterly reviews) coincide with monthly meetings, they shall replace monthly project meetings. These meetings shall be chaired by the Contractor's project manager or designated alternate. Contractor support personnel shall attend as required. The Contractor shall provide the agenda for each meeting to DOE for approval. The Contractor shall prepare a conference record to include action items for each of the meetings and distribute it within two weeks of each meeting. Informal technical interchange meetings will also be held as needed.

#### **5.11.4 Management Information and Reporting System**

The Contractor shall maintain the management information and reporting system that shall be consistent with DOE Contractor reporting requirements provided in Attachment II. The Contractor shall provide a brief (typically less than three pages in length) weekly progress report to DOE. Critical issues shall be identified in this report.

The Contractor shall maintain the commitments and agreements database file. These files shall include commitments and agreements with DOE, other Federal agencies, laboratories, and their contractors as necessary.

The Contractor shall maintain the engineering data file (e.g., internal project directives, project plans, travel reports, engineering memos, analyses, test reports, problem/failure reports, drawings, presentations, etc.) throughout the period of contract performance. The Contractor shall update monthly the index of the file. The Contractor shall make available specific file items to DOE on request.

The Contractor shall report on a monthly basis an assessment of work in progress. The Contractor shall measure and report on a monthly basis actual project expenditures and percent complete of work performed against the approved baseline plan using P3. In addition, a cost to complete calculation should also be reported. Actual project expenditures may be reported using software that can export cost data to P3. Reporting shall be consistent with the DOE Program Baseline Plan to an agreed-upon level of detail from the Contractor's WBS. The Contractor shall backup their current plan and forward the backed-up plan either by email or by overnight mail on portable electronic media to Orbital Sciences Corporation for integration into the DOE Program Baseline Plan.

#### **5.11.5 Interface with Government Laboratories**

The Contractor shall maintain interface activities with Government laboratories and facilities concerning fuel production and processing, heat source fabrication and assembly, MMRTG fueling and testing, and transportation to the launch site. The interface with the DOE fueling and test facility shall be defined in an IWA among (1) DOE Headquarters and the cognizant field office, (2) the DOE fueling and test facility, and (3) the Contractor. The IWA shall be prepared and maintained by the Contractor, jointly agreed upon by the DOE fueling and test facility and the Contractor, and approved by DOE. The Contractor's responsibilities and authority shall be defined in this document.

### **5.12 Quality Assurance and Reliability**

#### **5.12.1 Quality Assurance**

The Contractor shall maintain the QAP in accordance with the CRD, Attachment 1 of DOE

Order 414.1A, Quality Assurance, and SDPS/PQAR-1 (Revision 4), A Space and Defense Power Systems Programmatic Quality Assurance Requirements for Space and Terrestrial Nuclear Power Systems. The Contractor's QAP shall use national and international consensus standards (e.g., NQA-1, ISO 9001, etc.) in implementing quality assurance requirements. The scope, depth, and rigor of the QAP application shall be tailored by the Contractor based on the importance to safety and commensurate with contractual activities. The QAP shall include the policies and procedures for implementation of the QAP based on engineering and quality activities applicable to the specific contractual phase and shall be provided to DOE. The QAPP shall be updated, as required.

### **5.12.2 Reliability**

The Contractor shall update, as required, the Reliability Program. The detail of the reliability program shall be documented in a Reliability Program Plan in accordance with OSNP-3, "Reliability Program Requirements for Space and Terrestrial Nuclear Power Systems." The reliability task shall include Reliability in Design, FMECA, Failure Reporting documentation, etc., but will not include the performance of analyses and model development as required by OSNP-3, Section 4.4.

The Reliability Program Plan shall delineate the Contractor's methodology for planning, establishing, implementing, documenting, and maintaining control of a formal reliability program that will result in reliable mission performance with appropriate documentation. The plan shall demonstrate compliance with the requirements of those sections of OSNP-3 that will be performed during phases of the project.

The Contractor shall update, as required, the system FMECA, evaluate all test results in support of the FMECA for the system, address the impact of test results on the FMECA for the system, and identify all credible SPFs. All SPFs must be documented and approved by DOE.

The Contractor shall establish a closed-loop failure and corrective action system. Each failure shall be documented as required by OSNP-3. All failures shall be reported to DOE and discussed as part of the monthly progress reports. The Contractor shall list root cause and recommendations for corrective action to prevent recurrence of the failure, if applicable, as explained in OSNP-3.

### **5.12.3 Operations Analysis**

The Contractor shall support a programmatic OA. This OA will be a formal review conducted by DOE of the operations with emphasis on safety, safeguards assurance and investment protection. All operations in the "factory-to-flight" sequence involving nuclear fuel, heat sources, and MMRTGs shall be analyzed. The Contractor shall participate as a member of the OA team.

### **5.13 Resident Representative at Contractor Facilities**

The Contractor shall supply office facilities and services to accommodate two DOE on-site representative. Facilities are to include offices, desks, personal computers with email and Internet capabilities, tables, file cabinets, phone with voicemail, and copying and fax services. The Contractor shall provide unescorted badge privileges for the on-site representative(s) for access to all project activity areas.

## **PHASE VI (OPTION)**

### **6.0 SPARE FLIGHT MMRTG**

In the Phase VI Option, the Contractor shall fabricate, assemble, and acceptance test a spare Flight ETG. The Contractor shall support the fueling and acceptance testing activities at the DOE fueling and test facility. This phase may be associated with one or more of the mission specific phases (III-V). All terms, conditions, requirements, and specifications governing the contractual efforts of the mission specific Flight MMRTG shall also apply to the spare Flight MMRTG.

In support of this effort, the Contractor shall fabricate ground support equipment required to handle, monitor, and transport four MMRTGs at the launch site.

## DEFINITIONS

The following brief description of hardware terminology is provided as an aid in understanding the SOW described herein.

**CONVERTER** - The assembly of the generator which includes all elements of the conversion device, namely housing, end covers, thermoelectric components, insulation assembly, heater/heat source support systems, ancillary gas management, electrical power circuitry, instrumentation, and all other parts excluding the isotope heat source. Converter fabrication is the system Contractor's responsibility.

**ETG** - Electrically-heated Thermoelectric Generator - is comprised of a Converter and electrical heat source integrated assembly. The ETG is the Contractor's major assembled product.

**MMRTG** - Multi-Mission Radioisotope Thermoelectric Generator - is comprised of a Converter and isotope heat source (i.e., GPHS modules). The MMRTG is derived from an ETG via a fueling operation conducted at the DOE fueling and test facility. The fueling operation includes removal of the electrical heat source and replacement with a government furnished heat source assembly. Acceptance testing of the MMRTG is conducted by the DOE fueling and test facility.

**ACRONYMS and ABBREVIATIONS**

BOM	beginning of mission	LWRHUs	Light Weight Radioisotope Heater Units
CRD	Contractor Requirements Document	MMRTG	Multi-Mission Radioisotope Thermoelectric Generator
DOE	Department of Energy	NASA	National Aeronautics and Space Administration
DSAR	Draft Safety Analysis Report	NEPA	National Environmental Policy Act
ELV	Expendable Launch Vehicle	OA	Operations Analysis
EIS	Environmental Impact Statement	OSC	Orbital Sciences Corporation
ETG	Electrically-heated Thermoelectric Generator	P3	Primavera Project Planner©
FMECA	Failure Mode Effects and Criticality Analysis	PSAR	Preliminary Safety Analysis
FSAR	Final Safety Analysis Report	Pu-238	plutonium 238
GFE	government furnished equipment	QAP	Quality Assurance Program
GPHS	General Purpose Heat Source	QAPP	Quality Assurance Program Plan
INSRP	Interagency Nuclear Safety Review Panel	SARs	Safety Analysis Reports
IWA	Interface Working Agreement	SOW	Statement of Work
KSC/CCAFS	Kennedy Space Center/ Cape Canaveral Air Force Station	SPFs	Single Point Failures
		WBS	Work Breakdown Structure
		Wth	Watts thermal

### **Attachment IA - Firm Dates and Time Constraints**

The Contractor shall develop and recommend a preliminary schedule, including major milestones, for all phases of the contract utilizing the firm dates and time constraints provided below:

- The Contractor shall complete the Engineering ETG, including testing, within 18 months after contract award (i.e., Phase I duration is 18 months after contract start).
- For Phase II, the Contractor shall deliver the Qualification ETG to the DOE fueling and test facility by June 2004 and shall support the Qualification MMRTG testing at the DOE fueling and test facility (approximately 6 months).
- For Phase III, the Contractor shall provide the first Flight ETG to the DOE fueling and test facility by January 2006, and deliver the subsequent two ETGs, which includes the potential spare, on a schedule that allows 6 months (with overlapping of no more than 3 months) for each ETG to be fueled and tested at the DOE fueling and test facility. The DOE fueling and test facility must complete testing of all units by March 2009 and have the MMRTGs ready to ship by April 2009, 6 months prior to the potential October 2009 launch date.
- Similarly for Phases IV and V, the Contractor must deliver Flight ETGs to the DOE fueling and test facility to allow 6 months (with overlapping of no more than 3 months) for each ETG to be fueled and tested at the DOE fueling and test facility and allow the DOE fueling and test facility to be ready to ship 6 months prior to the potential launch dates.

### Appendix A: Enhanced General Purpose Heat Source (Conceptual Design)

The Contractor shall assume an enhanced General Purpose Heat Source (GPHS) for use on the MMRTG project. This enhanced GPHS module conceptual design provides added factors of safety in both module impact conditions and in hypervelocity scenarios, such as inadvertent earth gravity reentries. This conceptual design includes the addition of a 0.1 inch web in the center of the module between the graphite impact shells (GIS) and an increase of 0.1 inches in the thickness of the two module broad faces.

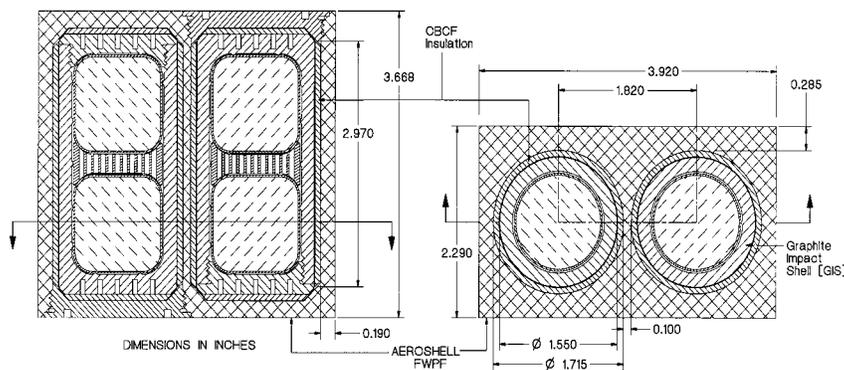


Figure 1: Enhanced GPHS Two-Dimensional View

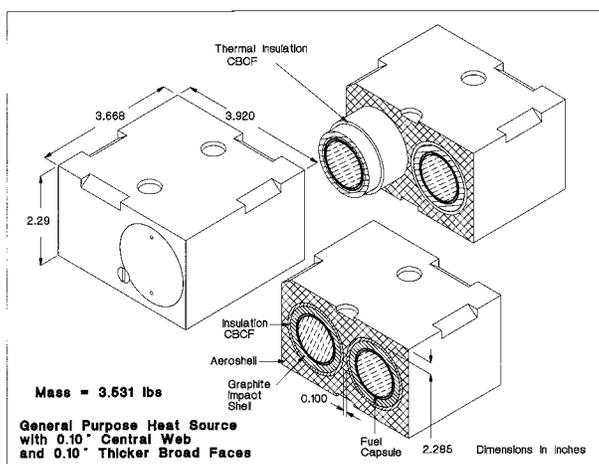


Figure 2: Enhanced GPHS Three-Dimensional View

**Table 1: Enhanced GPHS Mass Breakdown**

Component	Material	Mass (lbs)	Mass (grams)
Fuel Pellets (4)	Pu O2	1.323	600.000
Clads (4)	Iridium	0.501	227.200
Impact Shells (2)	FWPF - 3D Graphite	0.400	181.44
Floating Members (2)	FWPF- 3D Graphite	0.015	6.804
Insulator	CBCF - Graphite	0.019	8.618
Aeroshell (includes caps (2) & lock screws(2))	FWPF - 3D Graphite	1.273	577.429
Total		3.531	1601.49 1