Omnibus Multidiscipline Engineering Services (OMES)

Task Order 49 - EO-1 Mission Systems [redacted]

Modifications: 2

Task Value: $770K

Scope of Work:

The purpose of this mod is to extend the period of performance to March 31, 2017 with changes to the SOW integrated below from the original SOW.

The contractor shall provide support to the EO-1 satellite and ground systems. The contractor will also work [redacted] to support development of the HyspIRI Intelligent Payload Module Manager and other ESMO missions as needed:

1. Mission Systems engineering support:
   a. Operations oversight and anomaly resolution for EO-1(and other ESMO missions) flight and ground systems
   b. Design and development of advanced data processing services for instrument data within flight and ground elements for rapid response applications such as disaster management utilizing sensor web components and services.
   c. Automation of flight and ground system and sensor web processing service performance monitoring and reporting.
   d. Troubleshooting system problems, identification of system faults, and hands-on return to service on NASA local area network and the internet.
   e. Collaboration with system administration and network engineering on system security, user authentication and authorization, and IT/network scans.
   f. Downloading raw instrument data and processed products from various sites necessary for collaboration across multiple civilian satellite agencies; subsetting/tiling data spatially and temporally; generating images and map overlays from the data; calculating processing performance metrics; resampling/translation to different spatial coordinates; overlaying & combining data from multiple sources; comparing remotely sensed data to data from numerical models, calibration/validation campaigns, and/or other validation data sources; analyzing data related to data product utility; automating some of these tasks; diagnosing mission problems and developing & implementing corrections as part of the mission team and in context of NASA's role in the Committee on Earth Observations Satellites (CEOS) and the US Group on Earth Observations (GEO).
   g. Supporting data product testing and processing performance test verification.
2. Support the generation of manuscripts, presentations, reports, and proposals related to the above. This includes helping with the production of images, figures, tables, charts, as well as helping with the generation of the final document.
3. Organization and preparation of documentation of the activities in items #1 and 2, uploading of such documentation to appropriate websites, and organizing of information on those websites.

4. Development of processing capabilities implemented on cloud computing platforms based on the Amazon Eucalyptus operating system with Python scripting language integrating open source utilities such as GDAL and GeoServer to deliver web service capabilities. Knowledge of IDL, Matlab, Google Earth, and/or GIS software in Linux/Unix and real time Unix for flight elements plus Windows and MacOS for web browser integration.
5. Data transfers may be required from collaborator sites in other countries and international agencies such as the UN, World Bank, Red Cross, and other aid and relief organizations utilizing NASA satellites data for disaster risk management purposes.
6. Comply with NASA & GSFC rules regarding IT security, proper use, as well as ITAR and export control regulations. Take NASA & GSFC required training related to activities covered by this SOW. The successful candidate's citizenship or visa status + country of origin must allow unrestricted access to ITAR and export controlled information.

TASK DOCUMENTATION REQUIREMENTS/DELIVERABLE ITEMS:

Raw data from satellite and aircraft sensors downloaded onto suitable digital storage media.

Custom software and example data products to accomplish data processing & analysis tasks in above description.

Documentation for the data processing software sufficient [redacted] to understand, debug, run, and modify the software.

Documentation of raw data, processing steps, processed data, and analyses.

Any documentation shall be delivered in both electronic and (one) hardcopy form.

Presentation-related materials, hardcopy or electronic, as needed.

Travel, Materials, Etc. Known to be Required:

7. Place of Performance The work performed under this TO shall primarily be performed at the main GSFC campus or the JPSS Project annex location in Greenbelt, MD except for travel as noted in the travel section of this SOW.

8. Period of Performance: Period of Performance: May 13, 2013 thru March 31, 2017

9. Travel: Travel in support of technical meetings and required conferences [redacted] will be required if NASA travel policy will allow the travel. Typically, these meetings occur once every two months and vary in locations. The contractor will put a plan in place for these trips and [redacted] adjust the plan based on the upcoming NASA travel policy:

- JPL in September 2015
- Montreal in November 2015
- Namibia in Feb 2016
- Bonn Germany (For ENMAP coordination) in May 2016
- Beijing China for IGARRS in July 2016
- JPL in December 2016

Omnibus Multidiscipline Engineering Services (OMES)

Task Order 52 - JPSS Ground Mission Operations and Readiness

Period of Performance: 45 months

Modifications: 8

Task Value: $8.5M

Scope of Work:

The National Polar-orbiting Operational Environmental Satellite System (NPOESS) Preparatory Project (NPP) weather satellite is the first of several spacecraft planned under the National Oceanographic and Atmospheric Agency (NOAA) next generation weather satellite initiative. NPP was launched on October 28, 2011 in the afternoon orbit to primarily provide civil weather forecasting and climate monitoring data and is now referred to as Suomi National Polar-orbiting Partnership (SNPP). NOAA's new satellite program, the Joint Polar Satellite System (JPSS), is managed by NASA's Goddard Space Flight Center (GSFC), Greenbelt, MD. Japanese Aerospace Exploration Agency (JAXA) Global Change Observation Mission-Water (GCOM-W) satellites

The SNPP spacecraft was placed in a low polar Earth orbit (LEO) approximately 824 kilometers above the Earth at 98.7 degrees inclination. The SNPP satellite consists of the spacecraft [redacted] plus five instruments (ATMS, CERES, CrIS, OMPS, and VIIRS) built by various developers. The SNPP mission collects and distributes remotely-sensed land, ocean, and atmospheric data to the meteorological and global climate change communities as the responsibility for these measurements. It will provide atmospheric and sea surface temperatures, humidity sounding, land and ocean biological productivity, and cloud and aerosol properties.

The JPSS-1 weather satellite is the first in a series of spacecraft leveraging the work done by SNPP. It will have a similar compliment of instruments and science team members and similar orbital attributes. [redacted] It is tentatively scheduled for launch in FY2017. The Free Flyer Mission is another mission that the JPSS Ground Project will be supporting. Its launch is scheduled for no earlier than the summer of 2016.

In addition, ground system modifications were required to support other weather satellites including the Defense Meteorological Satellite Program (DMSP) and the Global Change Observation Mission – Water (GCOM-W) satellite.

The GCOM-W satellite was launched on May 15, 2011 by the Japanese Aerospace Exploration Agency (JAXA). Data from one of the sensors is downlinked at the Svalbard ground station and multi-cast back to JAXA and to NSOF. Testing of this interface will continue even after launch with modifications to the interface occurring that require further testing prior to going operational.

SNPP operations was transitioned to NOAA in March 2013. The NOAA will operate JPSS and FreeFlyer spacecraft after the LEO&A phase. All missions will operate at the mission operations center at the NOAA Space Operations Facility (NSOF) at Suitland, MD and coordinate spacecraft operations with the science team members.

A. Skill Set / Knowledge Required

The contractor shall have a strong technical base in the following areas:

- Spacecraft technical engineering
- Mission Operations engineering/analysts
- Ground Operations engineering

At a minimum, the personnel shall have the following skills:

- Experience in mission readiness/operations management and engineering skills
- Experience in ground system development, integration and test
- Task management
- Direct, relevant experience and familiarization with NASA/NOAA system architecture and organizational structures
- Strong ability to lead and interact with distributed team members and different corporate cultures
- Flight system engineering and operations
- Flight software databases and table management
- Command Telemetry databases

B. Summary of Work to be Performed

The objective of this task is to provide JPSS Ground Project Mission Operations Readiness services during the continued implementation of upgrades to the JPSS ground system for the SNPP and GCOM missions as well as implementation of the JPSS-1 and FreeFlyer missions. Key task activities include the planning and execution of operational readiness activities for current and future programs. Manage key readiness tasks such as rehearsal and operational readiness exercises, crew training and ground readiness test.

The SNPP/JPSS/GCOM Mission Operations Support Team (MOST) ensures that, processes, personnel, and procedures across the SNPP/JPSS/GCOM Mission System (flight and ground) achieve pre-launch readiness for early orbit, nominal, and contingency operations, and is responsible for post-launch activation, checkout, and calibration of flight and ground systems. Under this task, Contractor support is expected in the following areas: Spacecraft Engineering/Analysts.

For JPSS Ground Project MOST [redacted] of the JPSS Mission Operations Manager (MOM), the Contractor shall:

- Provide SNPP/J-1 spacecraft, instrument and orbital analysis expertise as part of the integrated MOST team. These analysts will provide expertise to develop, maintain and validate new and existing procedures for nominal operations as well as anomaly response. These analysts will be working closely with NOAA personnel and other members of the MOST team in mission operations readiness of the upgraded and future ground segment
- Manage the training and certification process for MOST and NOAA personnel for the upgraded systems. Individual will coordinate with JPSS Ground Project and Flight Project Contractors to ensure MOST and NOAA teams are trained and certified prior to operational readiness
- Develop and execute mission rehearsals and operational readiness exercise for operational readiness of NOAA and JPSS-1 MOST. This includes development of rehearsal/exercise plans and scenarios. Develop success criteria for meeting operational NOAA and MOST effectiveness/training.
- Support operational ground readiness and transition to operations activities for JPSS CGS to include development and execution of operational end-to-end data flow test with external organizations

Project Management

Provide the technical and functional activities at the contract level needed for administrative, clerical, documentation, quality assurance, and related functions.

Prepare a task management plan describing the technical approach, organizational resources and management controls to be employed to meet the cost, performance and schedule requirements throughout task execution.

Provide monthly financial reports to document plan versus actual expenditures.

Provide weekly status reports describing task performance and identify any issues.

Integration, Test, and Verification Services

Provide support to CGS integration, test, and verification activities in preparation to mission operations readiness and transition to operations. This includes supporting:

- Major program reviews
- Spaceflight subsystems
- Spaceflight instruments
- Spaceflight payloads

Travel [redacted] for engineering related activities.

Mission Systems Engineering

Provide systems engineering support for project development, reporting progress and conformance to appropriate practices and specifications (GPG 7120.5 Systems Engineering)

Provides support to key mission and spacecraft-level systems engineering functions that include:

- operations concept development
- architecture and design development,
- requirements analysis, identification and management,
- validation and verification,
- interfaces and interface control documents (ICDs),
- risk analysis, reduction and management and
- configuration management and documentation

Travel [redacted] for engineering related activities.

D. Deliverables / Milestones

SOW Work Summary Section	Deliverable Title	# Calendar Days After Award or Relative to Mission Schedule
C.1	Task Management Plan	Draft – 15, Final – 30
C.1	Status / Financial Report	Monthly
C.1	Weekly Status Reports	Weekly
C.2	[redacted] Spacecraft Technical Meetings	As Needed
C.2	Ground System Technical Interchange Meetings	As needed
C.3	MOM Status Meetings	Weekly
C.3	Mission Operations Working Group Meetings	Monthly
C.3	JPSS-1 Mission Planning Meetings	Bi-Weekly
C.3	FreeFlyer Engineering Meetings	As needed
C.3	Integration and Test Working Group Meetings	Weekly

SOW Work Summary Section	Deliverable Title	# Calendar Days After Award or Relative to Mission Schedule
C.3	Discrepancy Reporting Meeting	Weekly
C.3	Product Work Request Planning (WRRP) Meetings	Weekly
C.3	CGS Technical Meetings	As Needed
C.3	Operations CCB Meeting	Weekly
C.3	Mission Operations Reports	As needed

E. Other Direct Costs and Special Considerations

Travel

The following non-local travel is anticipated to support team meetings and other pertinent conferences:

Location	*Duration*	*# of travelers*	*Dates*
Aurora, Co- JPSS Ground CGS Technical Meetings, engineering reviews and test reviews (monthly)	[redacted]	[redacted]	*2 trips or (as needed)*
Boulder, CO-JPSS-1 Spacecraft Technical Meetings, engineering reviews and test reviews (monthly)	[redacted]	[redacted]	*2 trips or (as needed)*
Local travel to Suitland, Maryland (NSOF)and Riverdale, Maryland (CGS Contractor Facility)	[redacted]		*(as needed)*

E.2 Materials and Equipment

The place of performance will be on site at GSFC. Personal computers for on-site personnel will be provided by the JPSS Project.

No Government Furnished Equipment is planned. Local systems (GSFC on site) will be accessible for initial test procedure generation and pre-tests.

No Government Furnished Equipment is planned, although facility accommodations will be provided by NOAA at the NSOF for engineering support personnel. Facility taxes (telephone, IT support) will be provided by JPSS Project.

E.3 Special Considerations

This work may require access to other contractor proprietary information. Company-to-company non-disclosures agreements will be required.

Task members directly involved with test activities at secure facilities may require security clearances. The contractor shall coordinate and obtain concurrence [redacted] for individuals requiring clearances. Additionally, the contractor shall be compliant with the NASA security requirements and guidelines.

F. Applicable Documents

The applicable documents for this task include:

- NPP Schedule (Level 1 and Detailed Schedule to Launch)
- NPP Mission Requirements Specification
- NPP System and Operations Concept
- NPP System Engineering Management Plan
- NPP Risk Management Plan
- NPP Performance Verification Plan
- NPP System Integration and Test Plan
- JPSS Schedule (Level 1 and Detailed Schedule to Launch)
- JPSS Mission Requirements Specification
- JPSS System and Operations Concept
- JPSS System Engineering Management Plan
- JPSS Risk Management Plan
- JPSS Performance Verification Plan
- JPSS System Integration and Test Plan
- Applicable NPGs and GPGs
- NPR 7120.5D, NASA Space Flight Program and Project Management Requirements
- NPR 8000.4, Risk Management Procedures and Guidelines
- (FVS and FVTS documentation (ops manuals, ICDs, etc.)

Omnibus Multidiscipline Engineering Services (OMES)

Task Order 55 - STP-H5 Raven Development

Modifications: 5

Task Value: $16.5M

Scope of Work:

I. Summary of Changes in this Task Modification

This task modification adds scope to the following subtasks:

- Extend the period of performance of the Task Order through the end of FY16
- In Summary of Work: additional scope of work to cover test activities at the STP-H5 payload level
- Added Subtask 13: Raven on orbit commissioning and general science operations
- Updated travel requirements through end of new performance period
- Updated deliverable items & schedules through end of new performance period

II. Summary of Work

This Statement of Work (SOW) specifies work to be done and services to be provided to design, develop, build, and test of the Raven experiment—a real-time, autonomous vision experiment for relative navigation to fly to the International Space Station (ISS)—being managed by the Satellite Servicing Capabilities Office (SSCO) at the NASA Goddard Space Flight Center (GSFC). The Raven experiment is manifested on the Space Test Program – Houston 5 (STP-H5) payload managed by the Department of Defense (DoD) Space Test Program's (STP) Houston Office. Services rendered shall include engineering support including design of algorithms, writing of general documentation and mathematical specifications; hardware support, in the form of designing, building, testing, and operating flight hardware; and flight and ground software support, in the form of implementing and documenting algorithms, processing and analyzing data, and implementing and maintaining a version control system for software and documentation files. Services rendered for Raven shall also apply to SSCO support for STP-H5 payload level integration, test, and pre-flight closeout activities.

III. Period of Performance

The period of performance (PoP) shall be from the Authority to Proceed (ATP) until September 30, 2016.

IV. Subtask Description

Specifically, the Contractor shall provide the necessary personnel, engineering, facilities, resources and management required to complete the following tasks.

Subtask 1 – Program management support – This subtask includes management support for this task and ensuring that all of the deliverables are met as defined below [redacted]. Additionally, support is needed to facilitate quality assurance of procurements made by the contractor.

Subtask 2 – Systems engineering support – This subtask includes generating experiment- and component-level requirements, supporting the development of a concept of operations and detailed timelines, developing interface control documents, monitoring and reporting on design resource utilization such as mass, power, and communication bandwidth; and preparing verification and validation test plans. Experience in high-accuracy attitude control and estimation, as well as in pointing control systems, such as gimbals or fast steering mirrors, including the associated mechanical, electrical, and mathematical systems that drive them, is required.

Subtask 3 – Mechanical engineering support – This subtask includes designing, fabricating, assembling, analyzing, and testing of structural and enclosure elements of the Raven payload, as well as, developing requirements, integration and test plans, and verification plan for a motor-operated zoom lens. Required experience includes knowledge of GSFC mechanical design standards, analyses, and test methods; SSCO mechanical deign standards; understanding of the Raven pointing platform; space-ruggedizing stepper motors and SSCO ISS payload safety and quality requirements. Perform Craig-Brampton model reduction for STP-H5 payload.

Subtask 4 – Thermal engineering support – This subtask includes modeling, analyzing, and verifying overall experiment thermal design and control methods against requirements; as well as interfacing with the STP Houston office regarding the integrated STP-H5 thermal design. Required experience includes working knowledge of Thermal Desktop software, ISS thermal requirements, and standard GSFC practices for thermal analysis and control.

Subtask 5 – Electrical engineering support – This subtask includes designing, fabricating, assembling, analyzing, and testing electrical systems such as motor controllers, power distribution systems, and communication convertors, as well as designing, fabricating, and testing of electrical harnessing. Required experience includes stepper motor controller design, SSCO electrical design practices, ISS-derived electrical requirements, knowledge of the Argon power control unit (PCU), HDL programming, working with standard GSFC outside electrical suppliers, working knowledge of the universal serial bus (USB) physical link, Argon harnessing design, GSFC standards for harnessing manufacturing and testing, and ISS standards for ISS payload harnessing and grounding.

Subtask 6 – Flight software engineering support – This subtask includes designing, developing, coding, and testing command and data handling software to provide low-latency paths for inter-application, inter-processor, and inter-chip communications, as well as designing and developing vision processing algorithms—such as automatic gain and exposure control (AGEC)—for a variety of sensors, including visible, infrared, and flash lidars. Required experience includes C programming, hardware description language (HDL) programming, SSCO flight software architecture, SSCO command and telemetry definition tools, knowledge of cutting edge AGEC algorithms, GSFC Core Flight Software (CFS) and Core Flight Executive (CFE) products, and programming Xilinx field-programmable gate arrays (FPGAs).

Subtask 7– Simulation and control engineering support – This subtask includes generating simulations including high-fidelity orbit, attitude, and appendage dynamics, sensor and actuator models, and onboard algorithms for autonomous rendezvous and tracking using the GSFC Freespace simulation suite. Required experiences include building, using, and modifying a Freespace simulation and knowledge of advanced and novel control algorithms for motor-actuated robotic platforms.

Subtask 8 – Ground terminal engineering support – This subtask includes designing and implementing a ground terminal at GSFC to support Raven operations; interfacing with the Payload Operations and Integration Center (POIC); interfacing with the STP Payload Operations Control Center (POCC); and integrating custom ground terminal software into legacy ground terminal software. Required experience includes experience with Telescience Resource Kit (TReK); MSFC's POIC; ISS payload commanding; and Goddard Satellite Servicing Control Center (GSSCC).

Subtask 9 – Integration and Test engineering support – This subtask includes developing, writing, and executing integration and test plans and procedures, as well as, developing necessary electrical and mechanical ground support equipment. Required experience includes working knowledge of GSFC and SSCO practices on ground support equipment.

Subtask 10 – Engineering support activities – This subtask includes quality insurance and electrical, electronic, and electromechanical (EEE) parts evaluation.

Subtask 11 – Vision Navigation Sensor engineering support – This subtask includes implementing hardware and software modifications to government-owned hardware. This subtask is discussed in more detail in Appendix A.

Subtask 12 – Relative motion testing support – This subtask provides access to a relative motion test facility to test Raven sensor components. The relative motion facility must provide separation distances of greater than 50 meters and lateral offset motions of greater than 10 meters, in each cross-track axis. The contractor should assume at least two testing sessions of two weeks each (10 working days). Each session should include one day of integration activities, one day of de-integration activities, and bi-weekly telecons starting 8 weeks prior to the testing session and extending for 4 weeks after the testing session.

Subtask 13 – On Orbit Commissioning and General Science Operations – This subtask includes the on orbit operation of the Raven payload via the Goddard Satellite Servicing Control Center (GSSCC). It includes the writing of on-orbit procedures in the Timeline Management Tool (TMT) system, the execution of these procedures during Raven on orbit operations, the uploading of new flight software builds to the Raven hardware, and general operation and telemetry monitoring of the payload while on orbit. On orbit operations are expected to include approximately five (5) to ten (10) visiting vehicle trajectories spread between rendezvous and departures for four different visiting vehicles. Required experience includes a working knowledge of the overall Raven payload, Telescience Resource Kit (TReK), the Vispose Guidance Navigation and Control (GN&C) tool, as well as the Raven GSSCC facility.

In addition to these technical tasks, the contractor will document all algorithms, simulations, design documents, test documents, test reports using the Freespace Wiki, where appropriate, or the SSCO configuration management (CM) system. The contractor shall maintain all source code in a Concurrent Version System (CVS) repository provided by the Government.

V. Deliverable Items and Schedules

Deliverables for these tasks shall include reports and presentations describing system trade studies, design documents, algorithm mathematical specifications, analysis and test results, and participation in system software and hardware deliveries and delivery documentation [redacted]. Deliverables include the above items [redacted]

[redacted], all of which will produced by multi-disciplinary team from multiple contracting sources, and thus not a direct deliverable from this Task.

Specific deliveries under subtask 5 include the following electrical components:

- One (1) flight and one (1) engineering model Auxiliary Electronics Box
- Auxiliary Electronics Box ground support equipment (AEB tester and harnessing)
- One (1) flight and one (1) engineering design unit SpaceCube 2.0
- SpaceCube 2.0 ground support equipment
- Seventeen (17) flight harnesses
- Supplemental electrical ground support harnessing
- Thermal vacuum harnesses for Raven-level testing

The work performed under this task shall met the following delivery dates and project milestones:

- Final flight harness delivery: 11/21/2014
- Final flight component delivery: 12/2/2014
- Start I&T build up: 10/6/2014
- Raven vibe testing: 2/6/2015
- Raven thermal vacuum testing: 3/3/2015
- Raven final comprehensive performance testing: 4/1/2015
- Raven delivery: 4/15/2015
- Raven Operations Readiness Review (ORR): 01/20/2016
- Raven launch on STP-H5: 06/10/2016
- Raven on-orbit commissioning: June, 2016
- Raven on-orbit science operations: July through September, 2016

VI. Management Approach

a. Staff Allocation, Expertise, and Skill Mix

The contractor shall staff this work item with the appropriate skill mix and staffing level for the work.

b. Configuration Management

Systems and documents will be covered under the Servicing Capabilities Office Configuration Management Plan.

c. Quality and Mission Assurance

The contractor shall adhere to their Quality Assurance Plan, as well as, SSC-RQMT-008, "Space Servicing Capabilities Project Mission Assurance Requirements," and SSC-RQMT-009, "Space Servicing Capabilities Project Development Test Objective Product Assurance Implementation Plan" when developing flight hardware. SSC-RQMT-008 shall apply to procured hardware and software, where as SSC-RQMT-009 shall apply to in-house development hardware and software.

d. Facilities

Appropriate Information Technology devices to support the analyses, specification development, and report development are required. It shall be the contractor's responsibility to provide and set up local workstations and network connections at the contractor's off-site facilities as required, and to install any required tools and utilities on the contractor's equipment.

e. Risk Management and Best Practices

The contractor shall manage schedule, cost, and technical risk through monitoring and reporting of progress and performance metrics, identifying issues well in advance of negative consequences, recommending corrective action [redacted], and implementing corrective actions with the compliance [redacted].

f. Performance Metrics

The [redacted] will evaluate the work performed for this task based on technical merit. The [redacted] will utilize detailed performance metrics that reflect the contractor's performance in meeting research analysis, specific mission requirements, deliverables and delivery schedule, and the contractor's cost. The [redacted] technical evaluation of the task performance will be a subjective combination of performance metrics, technical quality of deliverables, cost control, significant events, innovations and meeting requirements set forth in the SOW.

g. Government Furnished Facilities, Equipment, Software and Other Resources

The Government will provide account and passwords to government-furnished workstations where existing versions of various relevant software packages shall be maintained. It shall be the contractor's responsibility to complete any GSFC required security-related training courses.

VII. Travel

Non-local travel is required for this task. The vendor shall cost travel for the following trips:

- Post-Payload Rack Check-out Unit (PRCU) testing @ KSC (December 2015): [redacted]
- ISS SpaceCube Experiment Mini (ISEM) reintegration / Raven functional testing @ KSC (February 2016): [redacted]
- STP-H5 wake from extended dwell and SpaceX-10 pre-flight closeouts (May 2016): [redacted]

VIII. Procurements

[redacted] limited to components such as commercial off-the-shelf (COTS) components, mechanical piece-parts, and mechanical hardware for prototyping purposes. [redacted] The contractor should expect that large purchases of hardware fabrication and assembly services will be handled by the Government.

Beyond what is stated above, the contractor shall procure an infrared camera and two-axis gimbal per the requirements and SOW provided by the Government.

IX. Work Location

This work shall be performed on-site at the Goddard Space Flight Center.

X. Reporting Requirements

The contractor shall report status in person or via teleconference [redacted] on a weekly basis. Reports shall include informal presentation of interim results, status of development activities, and action item status. The contractor shall provide all reports at least one day in advance of the monthly meeting via email, and maintain an email distribution list with the concurrence [redacted]. The contractor shall also support [redacted] in the preparation of status

reviews for internal and external funding agencies. The contractor shall comply with any and all additional requests for status meetings and reports. The contractor shall deliver all documents in portable document format (PDF) electronic form [redacted].

XI. Security Requirements

This task shall comply with Information Technology (IT) security requirements as documented in the Servicing Study IT Security Plan and the [redacted] IT Security Plan.

XII. Rights

This SOW shall adhere to the RIGHTS IN DATA – special works (FAR 52.227-17) as modified by NFS 1852.227-17.

Appendix A
[redacted] Vision Navigation Sensor Updates
Statement of Work

1. Summary of Work

This appendix to the statement of work defines the scope of work to be conducted under subtask 11, the implementation of hardware and software changes to a government-owned Visual Navigation Sensor (VNS), known as VADRE VNS, and [redacted] VNS, known as STORRM VNS, both built by [redacted]. The STORRM VNS is being loaned to the Government via a Space Act Agreement (SAA) between [redacted] and NASA GSFC. The SAA gives NASA permission to modify the STORRM VNS. Both VNS units are being provided as Government Furnished Property (GFP) to the contractor/subcontractor. This SOW gives the contractor/subcontractor permission to modify both VNS units.

2. Period of Performance

The period of performance for this subtask is the same as for the full task.

3. Work Details and Deliverables

The following section describes in detail the work to include under this subtask. Any requirements outlined in this section are driven by ground test goals and objectives and are subject to change at the discretion of the Task Monitor; such direction change would be outlined in a task modification.

VADRE VNS Modifications – The contractor shall remove the Processor Control Electronics (PCE) printed wiring assembly (PWA) and integrate a new build-to-print PCE PWA into the VADRE VNS unit. The contractor shall also debug VNS real-time calibration software and compare against simulated calibrations.

STORRM Modifications – The contractor shall integrate the existing VADRE VNS PCE PWA into the STORRM VNS unit and calibrate the Integrated Dewar Assembly (IDA) per [redacted] updated calibration process.

The combined change-out/calibration effort is expected to include the following high-level sequence of tasks:

- Functional testing of the STORRM VNS unit to provide a new baseline performance measurements
- Functional testing of the VADRE VNS unit to provide a new baseline performance measurements
- Disassembly of the STORRM VNS unit including de-mate and removal of the IDA from the internal electronics
- Disassembly of the VADRE VNS unit including de-mate and removal of the IDA from the internal electronics
- Test existing VADRE VNS PCE PWA
- Fabricate, assemble, and bench-top test new PCE PWA
- Calibration of the STORRM VNS IDA in [redacted] test setup. The calibration process is expected to produce a lookup table that maps input raw measured range and intensity values and IDA settings to an output corrected range value. The corrected range value accuracy and repeatability listed in Table 1 are goals of the calibration process. Intermediate range accuracy and repeatability requirements are determined by linearly interpolating between the two entries in the table that bracket the intermediate range.

- Reassemble STORRM VNS unit using VADRE PCE PWA and calibrated IDA and re-pressurize the VNS housing. After which, the STORRM VNS will be known as the "Raven VNS."
- Reassemble VADRE VNS unit using new PCE PWA and re-pressurize the VNS housing.
- Perform checkout of the Raven VNS unit
- Perform checkout of the VADRE VNS unit
- Repeat functional test of the Raven VNS to determine performance improvement
- Repeat functional test of the VADRE VNS to determine performance improvement

All STORRM/Raven VNS rework (PCE installation and re-calibration) work shall be completed by June 1, 2014, along with delivery of the following items:

- One calibrated Raven VNS unit: completely assembled and pressurized.
- Updated calibration tables to be used in the stand-alone calibration software architecture previously supplied by the contractor.
- Updated Windows/Wine executable of the stand-along calibration software that incorporated any bug fixes or functional updates
- Pre- and Post-Calibration test reports documenting functionality and performance prior to and after calibration.

All VADRE VNS rework (PCE installation) work shall be completed by September 30, 2014, along with delivery of the following items:

- One VNS unit: completely assembled and pressurized.
- Pre- and Post-assembly test reports documenting functionality prior to and after PCE PWA switch-out.

All additional calibration debugging and FPGA rework shall be complete by March 1, 2015.

Table 1: Corrected Range Accuracy and Repeatability as a Function of Separation Distance

Mean Range to Target	**1-σ Range Accuracy** (per pixel per shot)	**1-σ Range Repeatability** (per pixel per shot)
2 m	2 cm	2 cm
250 m	10 cm	10 cm
500 m	20 cm	20 cm
1 km	50 cm	50 cm

4. Mission Assurance Documentation

The work described above is subject to SSC-RQMT-000008, the SSCP Mission Assurance Requirements (MAR). The contractor shall report expected or suggested deviations to the MAR [redacted].

5. Travel

The contractor shall budget travel for [redacted] trips to the Houston area [redacted] to support the ISS safety review process.

6. Reporting Requirements

VNS Hardware Logbook—The contractor shall prepare a hardware logbook that will be the single repository of all activities conducted with or to the GFE. The [redacted] shall approve the method of physical logging this information, that is, the physical artifact.

Weekly Status Teleconferences—The contractor shall participate weekly status discussions to be conducted via teleconference. The expectation is that these meetings should be limited to 60 minutes in length.

Technical Interchange Meetings—The contractor shall participate in Technical Interchange Meetings (TIMs) as needed. These TIMs are designed to explore a topic in more depth than the team is able to complete in 60 minutes. TIMs shall be scheduled at least seven calendar days in advance and may be called for by either the contractor team or the Government.

Problem/Anomaly Reporting—The contractor shall notify NASA of any problem or anomaly within 24 hours of occurrence. The contractor shall use a system to document and track problems or anomalies that has been approved by the TM and the SSCO Safety and Mission Assurance Manager.

Government Notification—The contractor team shall notify the Government at least 5 working days prior to all mandatory inspections, test activities or deliveries at the contractor facilities to allow timely participation by the Government.

Pre-Ship Review—The contractor/subcontractor shall conduct a Pre-Ship Review after or during final functional and performance testing, but prior to shipping the GFE back to NASA, that covers the following material:

- As-Delivered Materials List (includes any updates from original delivery)
- As-Delivered Parts List (includes any updates from original delivery)
- Problem or Anomaly Reports
- Log of total operating time
- Log of total number of laser shots fired
- Log of mates and de-mates
- Test data showing verification of accuracy and repeatability numbers provided in Table 1

Omnibus Multidiscipline Engineering Services (OMES)

Task Order 59 - Assess JPSS Ground System Impact from Observatory Changes

Period of Performance: 24 months

Modifications: 1

Task Value: $618K

Scope of Work:

The Joint Polar Satellite System (JPSS) is the National Oceanic and Atmospheric Administration's (NOAA) next-generation operational Earth observation program that acquires and distributes global environmental data primarily from multiple polar-orbiting satellites. The program plays a critical role to NOAA's mission to understand and predict changes in weather, climate, oceans and coasts, and the space environment, which support the Nation's economy and protect lives and property. The JPSS provides operational continuity of satellite-based observations and products for NOAA Polar-orbiting Operational Environmental Satellites (POES) and the Suomi National Polar-orbiting Partnership (S-NPP) satellite. The first of two JPSS satellites, JPSS-1, is planned for launch in FY2017 with JPSS-2 to follow around the 2021 timeframe.

Description

This effort in this task will provide an assessment of the impact to the JPSS Ground System from changes to JPSS observatory instrument changes. Examples of these changes could be improved spatial resolution of the data that is provided by OMPS and CrIS combined with data compression of this data on the observatory downlink. Potential impacts to the ground system could include processing impacts resulting from decompression processing and the additional processing in creating science products with the increased resolution of the raw observed data.

Subtask One will focus on understanding the performance of the OMPS Limb Instrument. On-orbit OMPS Limb data will be analyzed for understanding instrument performance, including, but not limited to pointing accuracy and scattered light.

Scope and Specific Tasks

Provide an impact assessment on the JPSS Ground System that result from changes in instrument configurations on the JPSS observatories. Specific tasks include the following:

1. Work with the JPSS Project Scientists, Instrument Scientists and the JPSS Flight Project teams to understand potential technical performance of potential changes in the observatory instrument configuration.
2. Identify, document, and quantify the changes in the downlinked data resulting from JPSS observatory instrument configuration changes.

3. Work with the IDPS teams at NASA and Raytheon to determine potential technical performance and schedule impacts of implementing changes in the observatory instrument configuration.
4. Identify any requirements changes that are needed in the instrument, spacecraft, JPSS Ground System specifications, or algorithms specifications.
5. Support JPSS Program review preparations as required.
6. Provide summary reports of JPSS Ground System impacts from instrument configuration changes as required.
7. Subtask One
    a. Establish pointing accuracy by evaluating cloud height registration
        i. Compare the OMPS limb cloud heights with space-based LIDAR measurements
        ii. Quantify cloud height differences the LIDAR data with the goal of improving the OMPS-Limb cloud height algorithm
    b. Separate geophysical from thermal-induced pointing changes by analyzing cloud heights along the orbit track
    c. Develop documentation for the cloud height product
        i. Provide suggestions for organizing the OMPS-L h5 files .
    d. Support scattered light analysis by providing estimates of cloud amounts and cloud types

Deliverables and Delivery Schedule

ID	Title	Description	Periodicity
1	Monthly Status Report	Description of accomplishments, issues/concerns for the previous month and plans for the following month. Travel from the previous month, and planned travel for the upcoming month.	Monthly
2	Financial Report	533 financial report	Monthly, submitted with OMES report
3	Analytical Products	Reports and presentation material as required to develop and document the impact of the observatory instrument configuration changes on the JPSS GS. Reports and presentation material as required to develop and document the	[redacted] tracked in weekly and monthly reports

		performance of the OMPS-Limb cloud height data Peer-reviewed papers as appropriate	
4	Meeting minutes	Summary of results and actions from TIMs or other meetings that occur on this task.	Within one week of the completion of the meeting.

Place of Performance

The work performed under this TO shall primarily be performed at the contractor's location except for travel as noted in the travel section of this SOW.

Travel

Travel will be required in support of technical meetings with NASA Project, NASA Algorithm, and NASA IDPS, and Contractor Instrument personnel. No travel is expected in support of Subtask one.

Additional Considerations

Additional considerations for the task include:

8.1 Skill Set / Knowledge Required

(1) [redacted] required to have experience in the design, development and operations preparations of NASA ground systems including science data processing.

(2) [redacted] required to have experience with and knowledge of Earth observing instrumentation on board NASA satellites.

(3) Contractor shall comply with NASA's identity and credential issuance requirements. Staff may not begin working under this TO until a validated NASA identity with favorable background investigation adjudication is complete.

(4) The Contractor may be required to travel during the period of the Task Order (TO).

(5) Contractor will use computing resources supplied by NASA (e.g., networks, servers).

(6) [redacted] required to comply with NASA's training requirements including but not limited to security, environmental awareness, and safety.

8.2 Materials and Equipment

Personal computers for on-site personnel will be provided by the JPSS Program. Local systems (GSFC main campus and/or JPSS annex) will be accessible for initial test procedure generation and pre-tests.

8.3 Proprietary Information

This work may require access to other contractor proprietary information. Company-to-company non-disclosures agreements (NDAs) will be required.

8.4 Security Clearances

Task members directly involved with test activities at secure facilities may require security clearances. The contractor will coordinate and obtain concurrence [redacted] for individuals requiring clearances. Additionally, the contractor will be compliant with the NASA security requirements and guidelines.

8.5 Export Compliance

Interchanges with the Norwegian Space Centre (NSC) and their contractor, Kongsberg Satellite Services (KSAT) will be required. Appropriate agreements and arrangements will be required and information exchange will be assessed via the GSFC Export Control Office through the JPSS Ground Project.

This SOW identifies the OMES contractor's responsibilities to the broader engineering roles and responsibilities to NASA. The JPSS ground system is a distributed system that serves the weather prediction and climate research needs of NASA and NOAA. Interactions with foreign persons, specifically members of the Norwegian Space Centre (NSC) / Kongsberg Satellite Services (KSAT) is limited to planning, scheduling ground station assets for test events, execution of tests and troubleshooting of test issues. The scope of this interaction is limited to ensuring that all the system resources required for end-to-end mission system testing are available and ready to operate in an orchestrated fashion. More to the point, interaction is limited to ensuring that U.S. government property that is operated by KSAT under contract to both NASA and the ground system development contractor is available at specific dates and times as requested in order to support activities performed in CONUS.

Any technical issue arising from these requests falls under the responsibility of a separate and distinct U.S. Government contract.

Applicable Documents

The applicable documents for this task include:

- JPSS Common Ground System Requirements Document
- JPSS Concept of Operations Document
- FTS Level 3 requirements document
- FTS Concept of Operations
- JPSS Ground System Interface Requirements Documents
- Joint Polar Satellite System (JPSS-1) Mission System Specification (**MSS**)
- JPSS ATMS Performance Requirement Document
- JPSS CrIS Performance Requirement Document
- JPSS OMPS Performance Requirements Document (PRD)

- VIIRS Performance Requirements Document
- Applicable NPGs and GPGs
- NPR 7120.5D, NASA Space Flight Program and Project Management Requirements

Applicable Section from Omnibus Multidiscipline Engineering Services (OMES) Contract Statement Of Work

The applicable sections from the OMES contract SOW are provided below:

FUNCTION 3 – Implementation Phase Services

B. Mission Systems Engineering

1. **Architecture & Design Development:**
   a. Defining systems and conducting trade-off studies/design studies for spacecraft, suborbital craft, instruments, space segments and ground segments
   b. Reviewing software development and software system test activities
   c. Generating and maintaining and/or reviewing system block diagrams
2. **Requirements Analysis, Identification and Management:**
   a. Generating and managing and/or reviewing Level 1 and 2 requirements
   b. Conducting requirements traceability
   c. Documenting specified and lower level derived requirements to demonstrate that performance requirements are met
   d. Reviewing/performing independent design and development requirements analyses, and submitting comments and recommendations
   e. Reviewing technical specifications, and submitting comments and recommendations
   f. Providing specification of Requirements for Design, non-flight fabrication, and checkout of ground support equipment
   g. Reviewing contamination control requirements
   h. Reviewing operating plans and procedures for cryogenics, fuels, and other hazardous materials

C. Instrument Systems Engineering

1. **Instrument Data Processing Development & Support:**

   a. Developing the instrument data processing concept
   b. NA
   c. NA
   d. Developing Instrument operations concept.
   e. NA
   f. Analyzing flight anomalies and recommending implementing appropriate actions

g. Working with principal investigator and science working group in planning operations.

2. **Instrument Architecture & Design Development:**

a. Defining systems and conducting trade-off studies/design studies for instruments, space segments and ground segments.
b. Developing Instrument Architecture.

3. **Requirements Analysis, Identification and Management:**

a. Generating and managing and/or reviewing Level 1 and 2 requirements.
b. Conducting requirements traceability.
c. NA
d. NA
e. Reviewing technical specifications, and submitting comments and recommendations.

Omnibus Multidiscipline Engineering Services (OMES)

Task Order 61 - Maneuver Planning Support and Tool

Period of Performance: 35 months

Modifications: 3

Task Value: $568K

Scope of Work:

In FY15, [redacted] delivered a maneuver planning tool which provides a capability that reduces the time necessary to safely plan and evaluate optimal and non-optimal Risk Mitigation Maneuvers. This task is being revised in order to: provide for JPSS Block 2.0 capability, ensure adherence to DOC NIST 800-53 Rev 3 and Rev 4 IT Security Requirements, enhance RMM owner operator RMM planning capability to account for multiple missions (e.g. SNPP, JPSS-1, 2, 3, and 4), enhance RMM owner operator RMM planning capability to account for the exponential increase in the JSpOC space object catalog once DoD's new Space Fence comes on line in approximately 2 years. Additional task support includes statistical analysis for maneuver threshold targeting and collision probability forecasting.

1.1. Performance Requirements

This task is to provide the following:

- The contractor shall deliver a SNPP offline maneuver planning tool that integrates ephemeris, element sets, and vectors produced from the JSpOC and 614th AOC Detachment 1 satellite catalogs or owner/operators vectors to determine the optimum delta-V for satellite maneuvering to mitigate potential close approaches.

- The contractor shall deliver an automated system that automatically generates multiple avoidance maneuver plans given different time of day and control box constraints

- Optimal maneuver planning shall be completed within 10 minutes

- A single optimized maneuver ephemeris will be generated by the planning tool for screening for final confirmation with JSpOC.

- The automated system shall download the required JSpOC-generated data products from Space-Track.org or other location identified by satellite catalog provider.

- The tool should provide the number of sensor observations and/or residuals on each conjunction object used to produce ephemeris for conjunction assessment screening.

- The tool should provide a quality analysis of each secondary object that is considered a high risk object based on the JSpOC-produced data. Quality analysis is defined, but not limited, by (1) sensor observation span, (2) number of sensor observation gaps >3 hours, (3) number of sensor observations, percentage of sensor observations collected at perigee and apogee, and eccentricity of the secondary object.

- The tool should be database driven, run on a Windows machine, and have some probability calculation capability.
- The tool shall be compatible with JPSS releases 1.2 and 2.0.
- The tool shall be compatible with products with JSpOC Mission System (JMS).
- The tool shall have the ability to process JPSS GPS-based measurements, for use with the JSpOC High Accuracy Satellite Drag Model (HASDM).
- The tool shall perform statistical analysis, post predictive maneuver, to establish the remaining risk under various covariance forecasting scenarios.
- The system shall be compliant with applicable DoC cyber security requirements. Space-Nav shall perform gap analysis and provide periodic updates to maintain the system's cyber security compliance.
- The tool shall be capable of supporting both S-NPP and JPSS-1 satellites.
- The tool should be capable of being expanded to maintain up to 300,000 space objects in the Satellite Catalog, resulting from the increased detection capabilities of the DoD's new Space Fence.
- Phone support of the maneuver planning tool will be provided after installation and training.
- Provide CA consultation to operations.

1.2. [redacted] Place of Performance

It is estimated this task will require the following:

- [redacted] proven experience in developing and deploying satellite collision risk management capability. Place of performance is required at the contractor facility in Denver, CO. The tool(s) will be deployed at NSOF and the Consolidated Backup facility (CBU). Some travel will be required.

1.3. Assumptions

- The work performed under this TO shall primarily be performed at the contractor facility in Denver, Colorado except for travel as noted in the travel section of this SOW [redacted].
- Disclosure Agreements (NDAs) with vendors may be required. Specific NDAs will be determined during the execution of this task.

1.4. Applicable Documents

Document	Title	Source
TBD	Subcontractor Safety and Health Plan	Subcontractor
OMES-PLAN-0029	[redacted]	[redacted]
	Applicable NASA Procedures and Guidelines (NPGs)	NASA
	Applicable GSFC Procedures and Guidelines (GPGs)	GSFC

1.5. Deliverables

Engineering Documentation	Due Date
Preliminary S/W Design and Requirement Doc	45 days after task mod 3 gets awarded
Final R1 Detailed S/W requirements document	65 days after task mod 3 gets awarded
Final R2 Detailed S/W requirements document	09-Jan 2015
Operations Concept document	March 2015
R1 Test Plan and Procedures	18-Dec 2015
R2 Test Plan and Procedures	13-Mar 2016
R1 Training Material	18-Dec 2015
R2 Training Material 13-Mar, 2016	
Software Deliverables	**Due Date**
Provide for JPSS Blk 2.0 capability while continuing to support JPSS 1.2 interface requirements until SNPP operations fully transitions to JPSS Blk 2.0 and decommissions Blk 1.2	11-Dec 2015
Provide gap analysis of tool compatibility with NIST 800-53 Rev 4 requirements while supporting Rev 3 IT Security Requirement compatibility.	30-Oct 2015
Enhance RMM owner operator RMM planning capability to account for multiple missions (e.g. SNPP, JPSS-1, JPSS-2,...) with IT Security updates. (Release 2.0 with User's Guide)	13-Mar 2016
Enhance RMM owner operator RMM planning capability to account for the exponential increase in the JSpOC space object catalog once DoD's new Space Fence comes on line in approximately 2 years. – (Release 2.0 with User's Guide)	21-Aug 2016
Maintenance Release 3.1 with maintenance documentation	30-Apr 2017

Omnibus Multidiscipline Engineering Services (OMES)

Task Order 62 - Vision Navigation Sensor Flash Lidar Detector Re-Spin

Period of Performance: 26 months

Modifications: 2

Task Value: $TBD (current value $5.7M)

Scope of Work:

This task for the Omnibus Multidiscipline Engineering Services (OMES) contract requests support to redesign, fabricate, and test the next generation flash LIDAR Sensor Chip Assembly (SCA) for the Vision Navigation Sensor (VNS). This work is a continuation of the development activities funded by the Orion Multiple Purpose Crew Vehicle Project and the Satellite Servicing Capabilities Office (SSCO).

Summary of change in this Modification.

Additional development and testing including:

- Additional Program Management
- IDA Test Set Work-In
- Early SCA Testing
- FPGA Code Updates
- Additional TIM
- Calibration Drift Testing
- New Calibration Test Set Laser

Work Details and Deliverables

The Contractor shall provide the necessary personnel, engineering, facilities, resources, and management required to complete the following tasks.

Subtask 1 – Program Management and Systems Engineering:

The Contractor shall provide the appropriate project management and systems engineering tasks to support this work. This includes

- Developing, maintaining, and reporting to a schedule of activities with milestones including financial, technical, and schedule.

- Additional Technical Interchange meeting to be scheduled after [redacted] completes calibration testing of the first SCA delivered [redacted]. This TIM is referred to herein as, "TIM 2.5."

Subtask 2 – Re-spin VNS Detector:

The Contractor shall perform the following activities to advance the development of the VNS Sensor Chip Assembly (SCA) and Integrated Detector Array (IDA) during Phase 3 and 4 of this task.

1. FPGA code updates: The new IDA will require an update to the FPGA code that resides in [redacted] test set in order for the two to properly communicate. The full scope of these updates includes defining the changes, updating documentation, modifying the firmware and Special Test Equipment (STE), bench test modifications, and running a test with an IDA simulator for verification.

2. IDA Test Set Work-In: Includes early running of the [redacted] Focal Plane Electronics (FPE) with the IDA simulator to work out any bugs prior to the arrival of the IDA [redacted].

3. Early SCA Testing: Includes delivery of the first completed SCA [redacted] for early characterization testing. This early testing will confirm the findings of [redacted] probe tests as well as let [redacted] perform early detector calibration procedures to measure pixel to pixel variations in performance. These calibration test results will be the primary topic of discussion during TIM 2.5.

4. New Calibration Test Set Laser: The current [redacted] calibration test set laser does not have the ability to fully illuminate and excite the full IDA during calibration. This subtask includes the procurement and integration of a new laser into the test set as well as testing with the IDA simulator. The new laser is expected to cut down the time it takes to perform the IDA calibration as well as allow better measurement of pixel to pixel performance across the entire detector array.

5. Calibration Drift Testing: While the ROIC oscillation was determined to be the root cause and major contributor to the VNS' failure to meet range performance, there is still an overall system level offset whose root cause has yet to be identified. This subtask includes a root cause investigation to determine the source of this system level offset.

During the IDA testing phase (phase #4), the Contractor shall test the IDA against the requirements recently defined in the Satellite Servicing Capabilities Office (SSCO) document *Restore-L-RQMT-001778*, "Restore-L Rendezvous Proximity Operations (RPO) Subsystem 3D LIDAR Performance Specification."

Deliverable Items and Schedule

This task modification shall adhere to the deliverables schedule as laid out in the Task 62, Mod 0 Statement of Work with the exception of the TIM 2.5, which will be planned for an agreed upon date [redacted] during the Spring of 2016.

Travel

Travel may be required to support technical interchange meetings in developing the detailed ROIC design. The Contractor shall cost trips to the vendor site based n lessons learned from previous work.

Reporting Requirements:

VNS Hardware Logbook – The Contractor shall continue to prepare a hardware logbook that will be the single repository of all activities conducted with or to any GFE. The [redacted] shall approve the method of physical logging of this information, that is, the physical artifact.

Weekly Status Teleconferences – The Contractor shall continue to participate in weekly status discussions to be conducted via teleconference, preceded by a written outline of the technical status and any significant risks. The expectation is that these meetings should be limited to 60 minutes in length.

Problem/Anomaly Reporting – The Contractor shall notify NASA of any problem or anomaly within 24 hours of occurrence. The Contractor shall use a system to document and track problems or anomalies that has been approved by the Technical Monitor and the SSCO Safety and Mission Assurance Manager.

Government Notification – The Contractor team shall notify the Government at least 5 working days prior to all mandatory inspections, test activities or deliveries at the Contractor/sub-contractor facilities to allow timely participation by the Government.

Technical Interchange Meeting 2.5 – The Contractor shall participate in a TIM at the Contractor/sub-contractor's facility after completion of calibration testing of the first SCA delivered [redacted]. This meeting may be combined with a detector vendor site [redacted]. The TIM shall address:

- [redacted] Updates: Results of hybridization of ROICs into SCAs including yield, test results, oscillation observations, and overall status of [redacted] progress.

- [redacted] Updates: Results of SCA testing including calibration results, range performance, oscillation observations, adherence of SCA performance to the SSCO 3D LIDAR performance specification, as well as statuses of the additional activities authorized under Subtask 2 herein.

- Updates to estimate to complete (ETC) cost and current schedule status (schedule tracking metrics to be agreed to between the [redacted] and Contractor/sub-contractor team).

- Updates to any other additional relevant work completed.

Technical Calibration Data – GSFC requires delivery of the raw technical data gathered during the SCA and IDA calibration testing in order to perform their own independent determination of the re-spun detector's range performance. The Contractor/sub-contractor will provide all relevant information necessary for GSFC to interpret the raw data in its native form.

Management Requirements:

***Configuration Management* – Systems and documents will be covered under the Servicing Capabilities Office Configuration Management Plan.**

Quality and Mission Assurance – The Contractor shall adhere to their Quality Assurance Plan, as well as, SSC-RQMT-000008, "Space Servicing Capabilities Project Mission Assurance Requirements," and SSC- RQMT-000009, "Space Servicing Capabilities Project Development Test Objective Product Assurance Implementation Plan" when developing flight hardware. SSC-RQMT-008 shall apply to procured hardware and software, where as SSC-RQMT-009 shall apply to in-house development hardware and software.

Facilities – Appropriate Information Technology devices to support the analyses, specification development, and report development are required. It shall be the Contractor's responsibility to provide and set up local workstations and network connections at the Contractor's off-site facilities as required, and to install any required tools and utilities on the Contractor's equipment.

Risk Management and Best Practices – The Contractor shall manage schedule, cost, and technical risk through monitoring and reporting of progress and performance metrics, identifying issues well in advance of negative consequences, recommending corrective action [redacted], and implementing corrective actions with the compliance of [redacted].

Performance Metrics – The [redacted] will evaluate the work performed for this task based on technical merit. The [redacted] will utilize detailed performance metrics that reflect the Contractor's performance in meeting research analysis, specific mission requirements, deliverables and delivery schedule, and the Contractor's cost. The [redacted] technical evaluation of the task performance will be a subjective combination of performance metrics, technical quality of deliverable, cost control, significant events, innovation and meeting requirement set forth in the SOW.

Security Requirements – The task shall comply with Information Technology (IT) security requirements as documented in the Servicing Study IT Security Plan and the [redacted] IT Security Plan.

Rights – This SOW shall adhere to the RIGHTS IN DATA – special works (FAR 52.227-17) as modified by NFS 1852.227.17.

Omnibus Multidiscipline Engineering Services (OMES)

Task Order 63 - JPSS Ground Project DPES Support

Period of Performance: 31 months

Modifications: 2

Task Value: $15.9M

Scope of Work:

The Joint Polar Satellite System (JPSS) is the National Oceanic and Atmospheric Administration's (NOAA) next-generation operational Earth observation Program that acquires and distributes global environmental data from multiple polar-orbiting satellites. The JPSS Program plays a critical role to NOAA's mission to understand and predict changes in weather, climate, oceans, and coasts environments, which supports the nation's economy and protects lives and property. The National Aeronautics and Space Administration (NASA) is acquiring and implementing the JPSS, comprised of flight and ground systems on behalf of NOAA. The JPSS satellites are planned to fly in afternoon orbit and will provide operational continuity of satellite-based observations and products for NOAA Polar-orbiting Operational Environmental Satellites (POES) and the Suomi National Polarorbiting Partnership (SNPP) satellite.

NOAA is responsible for the JPSS program, while NASA is the program's procurement agent, and Goddard Space Flight Center (GSFC) is the lead for acquisition. The JPSS Ground Project, Goddard Code 474 under the Goddard JPSS Program Office is responsible for the design, development and deployment of the JPSS Common Ground System (CGS), a multimission command, control and communication and operational data production system. JPSS Ground Project primary customers are the weather Centrals Fleet Numerical Meteorology and Oceanography Center (FNMOC), Naval Oceanographic Office (NAVO), Air Force Weather Agency (AFWA) and the National Environmental Data and Information Service (NESDIS).

The Data Products Engineering and Services (DPES) segment of the Ground Project is responsible for the development, verification, and support of science algorithms in the CGS. This Task Order (TO) is issued to support the JPSS Ground Project DPES team for the acquisition to provide multidiscipline engineering support services for the study, design, systems engineering, development, integration, testing, verification, and operations of ground system hardware and software.

The contractor shall provide engineering subject matter expertise and project monitoring communication and coordination both within the JPSS Ground Project and with external providers in support of DPES activities. The data product validation and algorithm development teams under DPA direction are led by NOAA Center for Satellite Applications & Research (STAR) and include other contractors or NASA/NOAA partners or grantees that provide development, support or service to the JPSS Ground Project for operational algorithms.

Sub-task I: Government Resource for Algorithm Validation, Independent Test and Evaluation (GRAVITE)

GRAVITE Operators Shall:

- Start up and shut down GRAVITE processes as needed and according to
- regular procedures.
- Monitor and [redacted] report and/or log, various parameters
- that are indicative of whether the system is running properly.
- When problem conditions are discovered, remedy those conditions in
- order to keep the system operating.
- Provide the GRAVITE team, JPSS staff, and the Cal/Val community with
- problem reports or other information that may be necessary for the
- GRAVITE system to perform its functions.
- Collaborate with, and when necessary, provide guidance to, GRAVITE
- system administration, development and management staff as required for
- troubleshooting, maintaining and/or upgrading hardware and software.
- Coordinate operational activities with external mission partners (e.g.
- interface testing).
- Perform all the other tasks that are necessary to operate GRAVITE.

GRAVITE Developers Shall:

- Provide design, development, integration, testing, deployment of software modules, and user training support.
- Perform assigned software development as per NASA and/or NOAA (as applicable) software engineering policies and procedures.
- Participate in activities with external mission partners (e.g. technical interchange meetings, interface testing) [redacted].
- Support GRAVITE reviews (e.g. design reviews, code reviews).
- Coordinate with operators, system administrators, users, DPES staff, and external mission partners to support efficient use of GRAVITE.
- Communicate system status to management, operators, system administrators, users, DPES staff and external mission partners [redacted].

Sub-task II: Algorithm Integration Team (AIT)

- Algorithm Software Engineering:
- [redacted] the algorithm teams with the preparation and submission of
- Algorithm Change Packages (ACPs), Algorithm Discrepancy Reports
- (ADRs), Configuration Change Requests (CCRs) and associated and
- supporting documentary materials.
- [redacted] the algorithm teams with the use of the Algorithm Development
- Library (ADL).

- Receive ACPs from the algorithm teams.
- Perform integration testing in the G-ADA (see below) of ACPs submitted by the algorithm teams.
- When requested by DPES, provide successful ACPs to the CGS contractor.
- Provide general technical advice and assistance to the algorithm teams.

Algorithm Development Library (ADL)
(ADL is a set of tools and data enabling the user to perform development, analysis, maintenance, and testing of IDPS code and static data outside of the IDPS environment. ADL is developed and maintained by the CGS contractor. The University of Wisconsin provides certain ADL-related services to DPES.)

- Serve as DPES's technical liaison for ADL to the CGS contractor.
- Serve as DPES's technical liaison for ADL to the University of Wisconsin.
- Install and maintain an ADL user environment within the GRAVITE
- (Government Resource for Algorithm Validation, Independent Test and Evaluation) system.
- Provide DPES with general technical advice and assistance concerning ADL.

GRAVITE Algorithm Development Area (G-ADA)
(The G-ADA is a nearly complete instantiation of IDPS software in an IDPS-like hardware environment. The system provides an environment for development, analysis, maintenance and testing of IDPS code and static data in an actual IDPS environment.)

- Work as necessary with the GRAVITE system administrators to install new releases of the IDPS, including required COTS, into the G-ADA.
- Train DPES staff and/or algorithm team members in the use of the GADA, [redacted].
- Run algorithm tests or other computations in the G-ADA as requested by the algorithm teams.
- Support DPES in the evolution of the operations concept, requirements, design, etc., for the G-ADA.
- Develop custom software to support the G-ADA[redacted].
- Provide DPES with general advice and assistance concerning the G-ADA.

Common Configuration Management System ("Common CM") (The Common CM is a Clear Case-ClearQuest™ system, maintained by the CGS contractor, to provide government-side stakeholders with privilege-defined access to the IDPS software revision control system [in ClearCase] and to the IDPS software change management system [in ClearQuest]).

- Provide general administration of the government-side Common CM users, including enrolling and training users; providing user information to the CGS contractor so that user accounts may be created and maintained.
- Distribute to users any ClearCase-ClearQuest client-side software that may be needed for effective use of the Common CM (consistent with

licensing requirements and related guidance provided by DPES and the CGS contractor).

- Serve as DPES's technical liaison to the CGS contractor for Common CM.
- Provide DPES with general assistance and advice concerning the Common CM.

Project Coordination and Algorithm Implementation Support:

- Coordinate activities with external "givers" and "receivers" to identify, track, and mitigate issues.
- Maintain and support algorithm segment of DPES Integrated Master Schedule (IMS).
- Coordinate with JPSS Ground, AMP, STAR, and implementation management to build a concise and accurate DPES (algorithm) Level 4 and Ground Level 3 schedules.
- Monitor Detailed Rolling Wave (DRW) schedule.
- Schedule and coordinate algorithm implementation within IDPS.
- Support IDPS Build-to-Build (BtB) activities to include coordination of proposed code changes and requests for Factory Benchmark Test (FBT) and Integration, Test, and Check-Out (ITCO) data.
- Serve as Common Configuration Management (CM) lead and [redacted] in the coordination of the ADL updates between the DPES-AIT, STAR-AIT [redacted].
- Interact with DPES testing group to test weekly and monthly look-up tables (LUTs).
  - Serve as Systems Requirements Specification Parameter File (SRSPF) and Algorithm Change Management Plan (ACMP) "book boss" and provide inputs for the DPES Risk Boards.
  - Support the Algorithm Discrepancy Report Action Team (DRAT) in coordination and tracking of Discrepancy Reports (DRs), compilation of meeting minutes and facilitation of comments and concurrence by stakeholders.
  - Coordinate the weekly Discrepancy Report Action Team (DRAT), assist in the organization of the AERB, [redacted] Tier 1 meetings, participate and contribute to the Weekly Schedule Meetings, and participate in the Project
  - Monthly Reviews (PMR) Algorithm Splinter meetings [redacted].

Miscellaneous

- Provide DPES with other advice and services related to algorithm software engineering and DPES's support of algorithm Cal/Val, maintenance, integration, tools, data product quality monitoring, etc.

HDF5 Support

- HDF5 software development and maintenance support relevant to the distribution of JPSS sensor and environmental data products, with emphasis on the following

areas:

- Provide maintenance of JPSS-specific HDF5 software and features developed by The HDF Group.
- Test JPSS-specific HDF5 software on the platforms critical to JPSS users, including AIX and Red Hat Enterprise Linux.
- Provide support to JPSS HDF5 data users, providers, and engineers through helpdesk services and other means of communication with the JPSS community.
- Perform special maintenance tasks as identified and requested by DPES.
- Perform special research projects as identified and requested by DPES.
- Perform special development projects as identified and requested by DPES.
- Provide HDF5 training to DPES team and JPSS Cal/Val members.

Sub-task III: Field Terminal Support (FTS)

Provide support to the FTS node of the JPSS Ground System. There will be two phases of support for FTS: FTS SE/Development and FTS Operations (when FTS becomes operational):

FTS Developers Shall:

- Provide design, development, integration, testing, deployment of software modules, and developing FTS user guides for the FTS system.
- Develop assigned software as per NASA and/or NOAA policies as part of the JPSS Ground Project Data Product Engineering and Services (DPES) FTS team.
- Participate in activities with external mission partners (e.g. technical interchange meetings, interface testing) as needed.
- Support FTS reviews (e.g. design reviews, code reviews)
- Communicate system status to FTS management, DPES staff and external mission partners as needed.

FTS System Engineers Shall:

- Perform systems engineering activities for FTS.
- Perform systems engineering tasks consistent with applicable NASA systems engineering policies and practices.
- Coordinate with other JPSS Ground Project organizations, including JPSS Ground Software Assurance, Mission Assurance, Security, and Ground Project Integration and Test, as needed, to assure that FTS system is in accord with overall Ground Project objectives, plans and guidance.

FTS Operators Shall:

- Start up and shut down FTS processes as needed and according to regular procedures.
- Monitor and, as may be required, report and/or log, various parameters that are indicative of whether the system is running properly.

- When problem conditions are discovered, remedy those conditions in order to keep the system operating nominally.
- Provide the FTS management with problem reports or other information that may be necessary to perform its functions.
- Collaborate with, and when necessary, provide guidance to, FTS system administration, development and management staff as required for troubleshooting or maintaining/upgrading hardware and software.
- Coordinate operational activities with external mission partners (e.g. interface testing).
- Perform all the other tasks that are reasonably necessary to operate FTS.

DRL Support to FTS

This task will provide developers from the Direct Readout Laboratory (DRL) to support the FTS Node. The DRL is developing custom software technologies to work with S-NPP and JPSS science algorithms. The DRL will concentrate on the following areas of development:

- Developers shall update algorithm Science Processing Algorithms (SPAs) as new versions are made available.
- Developers shall update SPA libraries as new ADL versions become available.
- Developers shall create and implement an SPA maintenance model for the International Polar Orbiter Processing Package (IPOPP) framework.
- Developers shall update the IPOPP framework to comply with new and updated JPSS-1 algorithms.
- Developers shall update the Real-time Software Telemetry Processing System (RT-STPS) to comply with new and updated JPSS-1 algorithms.
- Developers shall update the H2G system to comply with new and updated JPSS-1 algorithms.
- Operate the DRL Direct Readout ground system and acquire S-NPP/JPSS data for signal and data integrity verification.
- Support direct readout users through information dissemination via the DRL web portal.

Sub-task IV: Systems Engineering Integration and Test (SEI&T):

DPES SEI&T staff members shall:

- Perform systems engineering activities, as applicable, for GRAVITE and FTS built, maintained and/or managed by DPES.
- Perform systems engineering tasks consistent with applicable NASA systems engineering policies and practices.
- Coordinate with other JPSS Ground Project organizations, including JPSS Ground Software Assurance, Mission Assurance, Security, and Ground
- Project Integration and Test, as needed, to assure that DPES-managed activities and systems are in accord with overall Ground Project objectives, plans and guidance.

Deliverables:

All deliverables shall be accepted [redacted] in writing. E-mail is an acceptable vehicle. If the deliverable is deemed unacceptable or incomplete, the [redacted] will state the reason and the deliverable shall be corrected by the contractor and resubmitted for acceptance.

Travel:

The contractor shall receive prior authorization [redacted] for all travel associated with the conduct of this SOW. Travel may be proposed for Technical Interchange Meetings (TIMs), workshops, conferences, special training needs and other engineering suppor t task activities [redacted]. Travel will be to meet with the ground system development contractor and observatory providers at contractor facilities (Aurora, El Segundo, Madison, etc.). [redacted] Local travel to the NOAA National Center for Weather and Climate Prediction facility in College Park, MD or the NOAA Satellite Operations Facility in Suitland, MD may be proposed as needed.

Government Furnished Items:

NASA shall provide office space within NASA/GSFC facilities for on-site personnel. Infrastructure, including computers, cell phones, blackberries, etc. shall also be provided where necessary. The place of performance will be on site at the GSFC JPSS facility (Building L40). Any conflicts discovered by the Contractor between the requirements in this SOW and any referenced specification herein shall be brought to the attention [redacted] for resolution.

Omnibus Multidiscipline Engineering Services (OMES)

Task Order 65 - MMS GN&C Constellation Simulation Development and Support

Modifications: 2

Task Value: $434K

Scope of Work:

This task requires simulation programming for the Magnetospheric MultiScale Mission (MMS). Tasks include augmentation of the existing MMS simulation using the GSFC Freespace Simulation Environment to improve fidelity, performance, usability and enhance external interfaces. The scope of this task includes those elements critical to the successful testing and development of the MMS GN&C Constellation High-Fidelity (CHiFi) simulator and MOC visualization tools.

Period of Performance
The period during which the work for this task shall be performed is January 1, 2015 through October 1, 2016.

Skill Set Required
Familiarity with the Freespace/Cenic development environment. Experience programming in ISO C, X11/Motif, OpenGL and knowledge of computer graphics, UNIX systems, data structures and multi-threading are required.

Deliverables/Milestones
Deliverable items are incremental patches to the existing Freespace/MMS code base, uploaded through the Freespace Version Control System.

Travel
The contractor is required to travel to GSFC on a total of nine (9) occasions to support code reviews and system level I&T support.

Work Location
This work may be performed at the contractors facility, but the contractor may be required to perform some work at the Goddard Space Flight Center.

GFE
None.

Subtasks
1. MMS HiFI Simulation Development -The contractor shall assist in the continuing development of the MMS Constellation High-Fidelity simulation in the GSFC Freespace Simulation Environment. Code patches will be integrated into the existing code structure. Subtasks will include but not be limited to the following:

Distributed Monte Carlo simulation launch and data collection utilities

- Enhancement of the visualization back-end appearance and MOC interfaces
- Implementation of a regression-test utility and suite
- Inter-simulation/hardware interface and protocol programming
- Support to developers with bug fixes on existing Freespace components

Reporting Requirements
The contractor shall verbally report status to the ACS leads on a weekly or bi-weekly basis. Written progress reports are required bi-monthly.

Applicable Documents
The services extended by this modification are in conjunction with the OMES contract SOW, Functions 1-B and 2-A.

Omnibus Multidiscipline Engineering Services (OMES)

Task Order 66 - Restore-L

Period of Performance: 26 months

Modifications: 1

Task Value: $39.8M

Scope of Work:

The Restore-L Mission provides robotic on-orbit servicing capability to operational satellites located in Low Earth Orbit (LEO), with extensibility to Geostationary Earth Orbit (GEO) and beyond. The primary objective of the mission is to transfer propellant to a client satellite to extend its operational life.

The Restore-L Mission would launch in the 2018-19 timeframe to provide client satellite refueling and life extension services. The Restore-L Mission consists of Restore-L Servicing Vehicle (RSV), Launch Vehicle (LV), and Ground elements. The Restore-L Servicing Vehicle (RSV) is the servicing spacecraft. It will rendezvous with and capture a client satellite with a propellant load, perform the required contracted services using robotic arms and tools, and then depart to a phasing orbit to await the next client.

The Restore-L Servicing Vehicle (RSV) consists of a Servicing Payload and Spacecraft Bus. The Servicing Payload includes a Rendezvous and Proximity Operations (RPO) Subsystem, Vision Sensor Subsystem, Robot Subsystem, Propellant Transfer Subsystem (PTS), and other supporting subsystems, as shown in Figure 1. Supporting Spacecraft Bus subsystems include Communications, Electrical Power, Thermal, and attitude control subsystems.

The Launch Vehicle (LV) Element is the Expendable Launch Vehicle (ELV) and corresponding support services. Also contained in this element are the integration and processing facilities and support functions, including all RSV specific Ground Support Equipment (GSE) and associated local ground control systems required.

The Ground Element consists of the ground system and all mission control functions which interface with existing ground stations to communicate with the RSV. The Ground Element will provide a mission operations center for the mission and establish communication networks between ground segments.

This Statement of Work (SOW) specifies work to be done and services to be provided in support of the Satellite Servicing Capabilities Office (SSCO) Restore-L Mission Study. This task provides support of all levels of Restore-L Mission Study system and subsystem engineering, technology development, system design, documentation, fabrication, integration and test, ground system development, and operations. It is organized to match the Restore-L Work Breakdown Structure (WBS) Elements, with subtasks generally aligned with anticipated Restore-L Mission

WBS Elements. Figure 1 illustrates the Restore-L WBS elements, and their tie-back to the SSCO (Code 408) matrix organization.

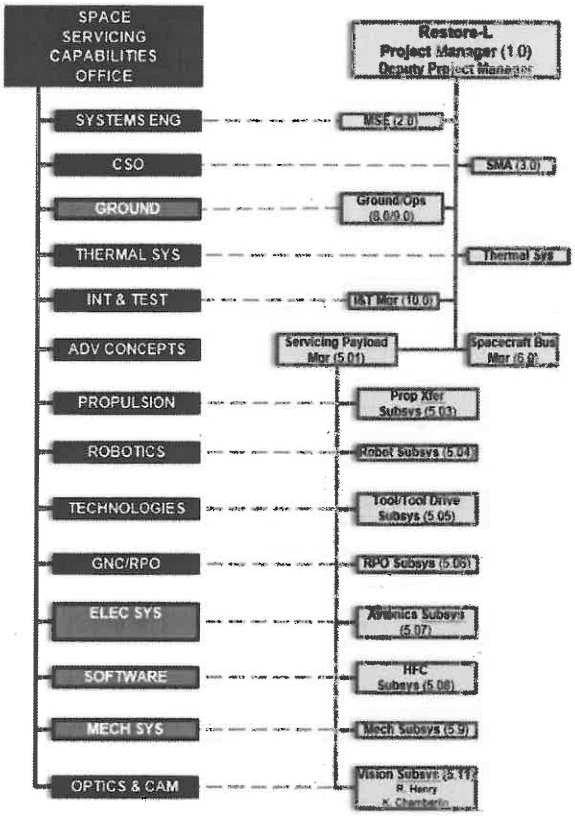

Figure 1 – Sub-task breakdown

As shown in Figure 1, FY15 work covered under this task is focused primarily on development of the Restore-L Servicing Payload architecture, requirements, interfaces, and associated technologies. Some early work is also included in the Spacecraft Bus Support and Ground elements.

Many Restore-L servicing technologies are directly applicable to asteroid capture and redirection mission concepts. This task includes all efforts applicable to both Restore-L and ARM. ARM-specific activities will be costed and tracked in a separate OMES Task, however some efforts in this task will be impacted. For example, ARM requirements will be incorporated into Restore-L component-level specifications to allow use of the components in both missions without redesign. Restore-L design reviews will include summaries of ARM requirements, including plans to accommodate ARM-specific requirements.

I. Summary of Work

The paragraphs below document anticipated Restore-L efforts and schedule in FY15 and FY16. As described in the *Deliverable Items and Schedule* section below, details of this

work are subject to change [redacted]. The remainder of this section is included for informational purposes only.

Project Management Support

The Contractor shall provide SSCO with appropriate manpower to support key system and subsystem management positions, as described below:

- RSV Deputy Manager (WBS 1.0)
- Restore-L Deputy Mission System Engineer (WBS 2.0)
- Restore-L Deputy Safety & Mission Assurance Manager (WBS 3.0)
- Restore-L Deputy Robot Subsystem Manager (WBS 5.04)
- Restore-L Tool and Tool Drive Subsystem Deputy Manager (WBS 5.05)
- Restore-L Payload Avionics Subsystem Manager (WBS 5.07)
- Restore-L Payload Mechanical Subsystem Manager (WBS 5.09)
- Restore-L Servicing Bus Manager (WBS 6.0)
- Restore-L Operations Manager (WBS 9.0)

System Engineering and Documentation support

Restore-L is a Pre-Phase A mission, which may progress to Phase A and or Phase B in FY15-16. This task includes system engineering and development of documentation for Restore-L as defined in NPR 7120.5 and NPR 7123.1, with tailoring as defined in the Restore-L Systems Engineering Management Plan (SEMP).

System engineering support includes but is not limited to structural, mechanical, electrical, thermal, data systems, environments, reliability, risk tracking, system architecture definition, contamination etc.

Required documentation includes but is not limited to: 1) mission requirements at all levels; 2) mission concept of operations; 3) sub-system specifications; 4) technology development plans; 5) technology development test reports; 6) interface control documents; 7) integration and test procedures and reports; 8) validation and verification and plans and reports; 9) analysis, drawings and models; 9) risk management plans and assessments; etc.

Hardware and Software Design, Analysis, Fabrication, and Test

FY15-16 efforts will include the design, analysis, fabrication, integration, and test of Restore-L ground support equipment, and Servicing Payload components, EDUs, and in some cases long lead flight hardware. Hardware and software to be developed will be as

required to support the system and subsystem Restore-L and Asteroid Redirection Mission schedules shown in Figure 2**Error! Reference source not found.**.

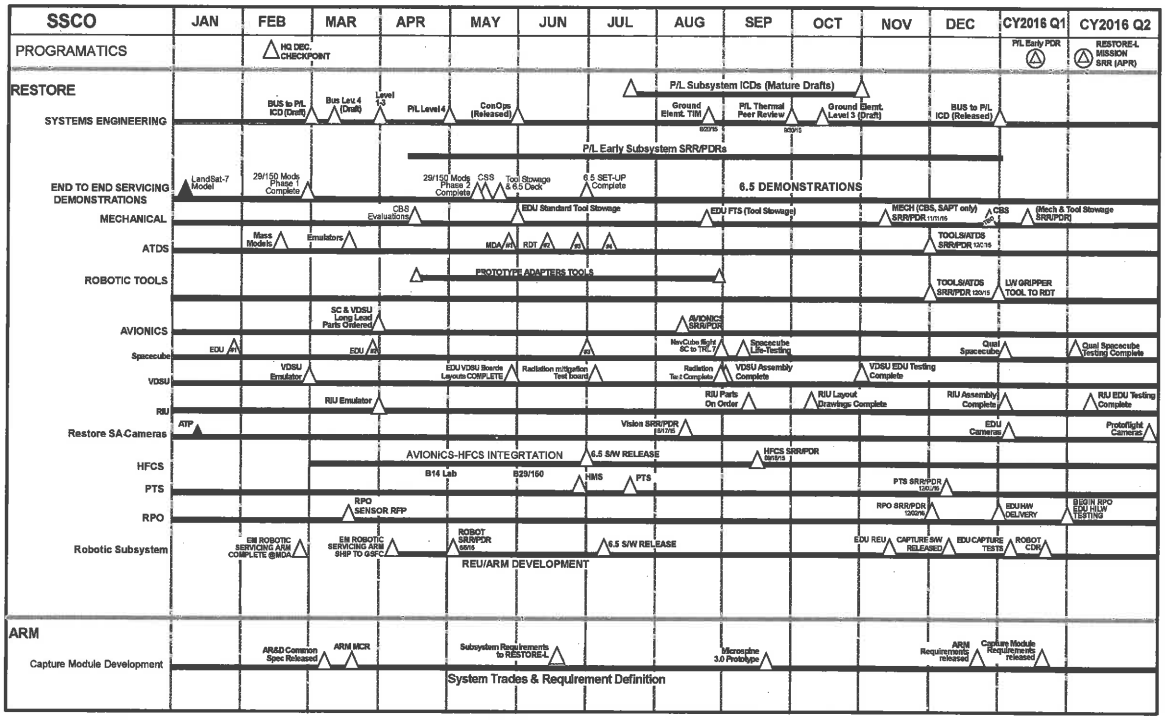

Figure 2 – Task 66 POP Summary Schedule

II. Subtask Description

Staffing, fabrication, and procurement to achieve the Restore-L Mission objectives in the *Summary of Work* section shall be proposed and reported in the subtasks shown in Table 1. Some WBS elements/subtasks not currently required are listed as "*Reserved*" for future use.

Table 1 - Subtask Descriptions

OMES Subtask Number	Restore WBS Number	WBS Element	Subtask Description
101	01	Restore Project Management	Includes management of the Restore-L project.
201	02	Restore System Engineering	includes support of the Restore-L Mission System Engineer.
301	03	Restore S&MA	includes support of the Restore-L S&MA Manager.
401	*04*	*Reserved (Science & Technology)*	*Not funded in this Mod*
501	*05.01*	*Reserved (SP Mgmt)*	*Not funded in this Mod*
502	*05.02*	*Reserved (SP Sys Eng)*	*Not funded in this Mod*
503	05.03	PTS Subsystem	includes support of the Restore-L Propellant Transfer System (PTS) Subsystem Manager
	05.04	Robot Subsystem	
541	05.04.01	Robot Sys Eng	includes support of the Restore-L Robot Subsystem Manager
542	05.04.02	Robot Arm	includes all work related to the design, build, and test of the servicing robot arm, as defined in "*Appendix A: Robot Subsystem Flight System Risk Reduction in Support of Satellite Servicing*" (see file Restore_OMES_Task66_AppendixA.docx on the OMS System.)
543	05.04.03	Robot Electronics Unit (REU)	includes all work related to the design, build, and test of the Robot Electronics Unit, as defined in "*Appendix B: Robot Electronics Unit (REU) Flight System Developement in Support of Satellite Servicing*" (see file Restore_OMES_Task66_AppendixB.docx on the OMS System.)
544	05.04.04	Robot Flight Software	includes all work related to the design, build, and test of the Restore-L robotic flight software.
	05.05	ATDS & Tools	
551	05.05.01	ATDS SEI&T	includes support of the Restore-L Tool Drive Manager
556	05.05.XX	Tools	includes support of the Restore-L Tools Manager
	05.06	RPO Subsystem	
561	05.06.01	RPO SEI&T	includes support of the Restore-L RPO Subsystem Manager.
562	05.06.02	RPO Flt Software	includes RPO flight software development and test
563	*05.06.03*	*Reserved (RPO Hardware)*	*Not funded in this Mod*
	05.07	SP Avionics Subsystem	
571	05.07.01	SP Avionics Sys Eng	includes support of the Payload Avionics Manager
572	05.07.02	SpaceCube	includes support of the SpaceCube Responsible Engineer
573	05.07.03	RIU	includes support of the RIU Responsible Engineer
574	05.07.04	VDSU	includes support of the VDSU Responsible Engineer
575	05.07.05	Harness	includes support of the Harness Responsible Engineer
581	05.08	Hybrid Flight Computing (HFCS)	includes support of the Restore-L HFCS manager
591	05.09.01	Mechanical Subsys SEI&T	includes support of the Restore-L Payload Mechanical Subsystem Manager
510	05.10	Servicing Payload I&T	includes support of the Restore-L Payload I&T manager
511	05.11	Vision Subsystem	includes support of the Restore-L Vision Subsystem Manager
601	06	Reserved (Spacecraft Bus)	*Not funded in this Mod*
701	07	*Reserved (Launch Vehicle)*	*Not funded in this Mod*
801	08	*Reserved (Operations)*	*Not funded in this Mod*
901	09	Ground	includes support of the Restore-L Ground System and Operations Manager
10	10	*Reserved (RSV Integration & Test)*	*Not funded in this Mod*

III. Deliverable Items and Schedules

Deliverables for these tasks shall include reports and presentations describing system trade studies, design, participation in component, subsystem, and system-level reviews, ground tests, etc, and algorithm mathematical specifications, analysis and test results, and ground system software deliveries and delivery documentation as defined by the Task Monitor. Deliverables include the above items [redacted] all of which will be produced by multi-disciplinary team from multiple contracting sources, and thus not a direct deliverable from this Task. Specific deliverables for this task are monthly progress reports delivered [redacted] on the last Thursday of the month, and presented at the first opportunity following that date, additional deliverables for Subtask 542 as listed in Appendix A, for Subtask 543 as listed in Appendix B, and for all subtasks as listed in *"Appendix C: Statement of Work (SOW) for End-to-End Refueling Demonstration in Support of Satellite Servicing "* (see file Restore_OMES_Task66_AppendixC.docx on the TOMS system.).

IV. Management Approach

a. Staff Allocation, Expertise, and Skill Mix

The contractor shall staff this work item with the appropriate skill mix and staffing level for the work. Some manpower positions shall be filled with individuals possessing an active Top Secret Security clearance or better.

b. Configuration Management

Systems and documents will be covered under the Servicing Capabilities Office Configuration Management Plan.

c. Facilities

Appropriate Information Technology devices to support the analyses, specification development, and report development are required. It shall be the contractor's responsibility to provide and set up local workstations and network connections at the contractor's off-site facilities as required, and to install any required tools and utilities on the contractor's equipment.

d. Risk Management and Best Practices

The contractor shall manage schedule, cost, and technical risk through monitoring and reporting of progress and performance metrics, identifying issues well in advance of negative consequences, recommending corrective action [redacted], and implementing corrective actions with the compliance [redacted].

e. Performance Metrics

The [redacted] will evaluate the work performed for this task based on technical merit. The [redacted] will utilize detailed performance metrics that reflect the contractor's performance in meeting research analysis, specific mission requirements, deliverables and delivery schedule, and the contractor's cost. The [redacted] technical evaluation of the task

performance will be a subjective combination of performance metrics, technical quality of deliverables, cost control, significant events, innovations and meeting requirements set forth in the SOW. The primary performance tracking mechanism for this task shall be via a "ticket system" to track earned value. Each monthly progress report shall document open issues assigned to contractor in the "Issue Tracker", and the number of issues closed in that period. Close-out of issues will track value earned. The Issue Tracker is available at https://128.183.228.128/hst/mantisbt-1.2.9. Contact the Task Monitor to gain access.

f. Government Furnished Facilities, Equipment, Software and Other Resources

The Government will provide account and passwords to government-furnished workstations where existing versions of various relevant software packages shall be maintained. It shall be the contractor's responsibility to complete any GSFC required security-related training courses.

V. Travel

Non-local travel is required for this task. Travel requirements will include, but not limited to, Kennedy Space Center, Johnson Space Center, West Virginia Robotics Lab, and Restore-L partner and vender site visits.

VI. Work Location

This work shall be performed primarily on-site at the Goddard Space Flight Center, but the contractor may be required to perform some work at the contractor's facility, at the Naval Research Laboratory, and at several other NASA and contractor test facilities.

VII. Reporting Requirements

The contractor shall report status in person or via teleconference [redacted] on a weekly basis. Reports shall include informal presentation of interim results, status of development activities, and action item status. The contractor shall provide all reports at least one day in advance of the quarterly meeting via email, and maintain an email distribution list with the concurrence [redacted]. The contractor shall also support [redacted] in the preparation of status reviews for internal and external funding agencies. The contractor shall comply with any and all additional requests for status meetings and reports. The contractor shall deliver all documents in portable document format (PDF) electronic form [redacted].

VIII. Security Requirements

This task shall comply with IT security requirements as documented in the Servicing Study IT security plan for all systems.

IX. Rights

This SOW shall adhere to the RIGHTS IN DATA – special works (FAR 52.227-17) as modified by NFS 1852.227-17.

Appendix A - Restore-L Robot Subsystem Development

BACKGROUND

The Satellite Servicing Capabilities Office (SSCO) at the NASA/Goddard Space Flight Center is maturing technologies necessary to enable servicing of satellites in space and reducing the risk of such a mission. Over the last four years, the Office has used a variety of industrial robotic platforms to simulate robots working in space to develop and test algorithms required for autonomous and teleoperated control of space robots, to evaluate robotic tools, and to integrate various components of a robotic system needed to service satellites.

In order to integrate and test new sensors and tools, further develop the necessary robot control algorithms, and validate the testing done to date on the industrial robots, SSCO began the procurement a flight-like Engineering Development Unit (EDU) Robotic Arm and Robot Electronics Unit (REU) in FY14 with delivery scheduled in early CY15. Continuing to support the EDU Robotic Arm and REU and maturing the design to a fully flight compatible robot subsystem is the focus of FY16 and FY17 efforts.

SCOPE

The Contractor shall provide systems and discipline engineering support for the evaluation of the EDU robotic arm and REU as well as maturing the design to a fully flight compatible robotic arm in support of satellite servicing.

CONTRACTOR TASKS

On a time and materials basis, the contractor shall perform work addressing scientific, programmatic, and engineering topics related to the Robot Subsystem architecture, design, manufacture, integration and test, and/or operations. The scope of this work will be defined by tasks [redacted]. In addition to engineering support labor, these tasks may incur incidental costs, including, but not limited to, materials, travel, miscellaneous other direct costs, and associated burdens. These tasks will generally provide systems and discipline engineering support of the following flight design tasks:

1. Support Restore-L Reviews
   Labor resources for preparation, participation, and post review follow-up (action item compilation) for the Robotic Arm PDR, REU PDR, Robot Subsystem PDR, Robotic Arm CDR, and REU and Robot Subsystem CDR.
2. Robotic Arm NRE
   Mechanical engineering and analysis support to mature the state of the Restore EDU Robotic Arm design toward flight pedigree for the Restore-L and ARRM missions. The task is generally broken down as follows:

   A. Provide mechanical engineering support as requested to advance
   B. Provide mechanical analysis support for the Restore-L Robotic Arm flight design
   C. Provide mechanical engineering and analysis support to the ARRM team in evaluations of the existing Restore Robotic Arm design to meet requirements for the asteroid mission.

3. Robotic Arm Procurements

   Procure the following flight components for two flight arms and one flight spare

   A. RPBs
   B. Inductosyns™
   C. Flex harnesses
   D. Arm tube assemblies
   E. Force torque sensors
   F. Force torque sensor electronics

4. Assembly and characterization of two flight wrist pitch actuators

   This task includes labor hours to assemble two flight wrist pitch actuator assemblies to be built to the flight design. The gearmotor will be characterized at ambient and at temperature, and the actuator will be subjected to dyno, accuracy, and inertia characterization in ambient conditions prior to delivery. An End Item Data Package, similar to previous robotic arm actuator builds, will be delivered as well.

5. Robot Electronics Unit

   This task supports:

   A. Modification or retrofitting of the EDU JCBs as required.
   B. Design, development, and analysis of the EM and flight JCB including, but not limited to, schematic capture, FPGA code updates, ASIC development, documentation updates, and board fabrication and test support.
   C. Updates to the existing JCB Emulator.
   D. Updates to the MCAPs GFE software and associated documentation.
   E. Design, development integration, and test of an REU EDU Rack Mark 2 which will contain EM JCBs in a rack form factor inclusive of an updated FPGA daughter board.
   F. General REU engineering support as required.

6. Simulation Tools

   Provide simulation tools that support ongoing arm performance analyses, simulation tools that support actuator and arm tuning, and data analysis tools that support actuator and arm test analysis building on tools previously delivered to GSFC. The effort includes the following tasks:

   A. Update the Workspace Analysis Tool
   B. Create an Actuator Tuner Tool
   C. Create a Robotic Arm Data Analyzer
   D. Provide a consistent level of support to the rest of the simulation team relating to the simulation tools.

7. General Engineering Support

   This task provides a consistent level of support of the EDU and flight trade studies to include the following subtasks:

   A. EDU upgrades to include, but not limited to, camera flex uninstall and install, RPBs uninstall and install, and EDU force torque sensor electronics white wire fix.
   B. EDU test support
   C. Flight requirements support
   D. TIM support
   E. Low level of engineering support to include, but not limited to, supporting the RPB troubleshooting effort, reviewing test procedures and results, providing timely answers to robotic arm related questions, etc.

The Contractor shall provide systems engineering services in support of the effort described above. The systems engineering effort will include hardware design, interface control planning and documentation, fabrication, subassembly testing, integration, subsystem testing, and post-delivery support. The effort will require the contractor to provide material and parts purchases, fabrication, and assembly support for hardware, and software support. The Contractor shall also provide the necessary Program Management and Quality Assurance to support the contract activities.

Technical Management

The Contractor shall integrate management disciplines, functions, and systems into an overall management activity to achieve cost-effective planning, organizing, controlling, and reporting of technical approaches, technical progress, schedules, resources, and time relationships. The Contractor shall provide the project management for the overall technical and business planning, organization, direction, integration, control, and approval actions needed to accomplish the objectives [redacted]. Computer-based tools shall be used to communicate the content and track the status of all activities for which the Contractor is responsible [redacted]. The Contractor shall report programmatic and technical issues as soon as they arise. The Contractor shall give the Government complete access and insight into all programmatic activities and meetings. The Contractor shall develop, implement and maintain a Management Plan (PM-01) for the [redacted] effort.

Resources Management

The Contractor shall be responsible for providing the financial management necessary for the financial control and reporting [redacted].

Schedule Management

The Contractor shall develop, maintain, and analyze start-to-finish program schedules to manage design, development, and production. The Contractor shall implement an effective update process on a regular basis to ensure that resources are being used effectively. The Contractor shall report schedule issues as soon as they arise.

The Contractor shall report its schedule performance and the status of potential and/or actual project changes, analyze the effect of schedule changes, and identify corrective actions and/or work-around plans to meet contract requirements. Changes that affect the schedules of other subsystems, external systems, milestones, or the scheduled system critical path shall be subject to prior approval of the Task Monitor. Schedule changes not affecting the schedules of external systems or the critical path do not require Task Monitor approval.

The Contractor shall describe the development, maintenance and access to its schedules in its Management Plan (PM-01).

Configuration Management

The Contractor shall define, implement, and maintain a Configuration Management (CM) Program. The Contractor shall prepare, submit, and maintain an approved Configuration Management Plan (PM-02) describing the requirements, approaches, and procedures for implementing its CM Program. This plan shall document the contractor's approach to specifying, documenting, controlling, and maintaining visibility and accountability of all aspects of the Contractor's activity.

Data Management

The Contractor shall maintain an up-to-date Data Management System. The Contractor shall deliver in electronic format all required data, reports, presentation materials and documentation to all identified SSCO elements, contractor elements, and other SSCO partners. Document production and issuance shall include original preparation as well as subsequent revision and maintenance through [redacted] completion.

Project Reviews

The Contractor shall participate in the preparation and presentation of reviews that measure and establish compliance with cost, schedule, and technical milestones, and demonstrate fulfillment of the [redacted] requirements. The major reviews shall be informal and formal, electronic-media-based, and technically oriented. The Contractor shall support the preparation of a detailed review package, including references for each review. The Contractor shall participate in a dry-run presentation as needed and shall support the SSCO in defining the review agenda and contents. All action items shall be tracked to completion and the resolution and rationale recorded as part of the closure. The Contractor shall support the SSCO during Project-Level Review Board meetings and related reviews.

Travel

The Contractor shall provide all necessary travel to implement the contract effectively.

Task and Procurement Management

The Contractor shall propose a WBS (PM-07) and be responsible for traceability and reporting of all subcontractor cost and scheduling data within the associated WBS elements to the level shown in their WBS. The control of these data and reporting for WBS elements subcontracted by the Contractor shall remain the responsibility of the Contractor.

The Contractor shall ensure that all of the work performed under this task is compliant with current United States export control laws and regulations.

Property Manangement

The Contractor shall provide overall property management for real property (government furnished equipment, mechanical ground support equipment, electrical ground support equipment, etc.) for which they are accountable [redacted]. The Contractor shall procure and deliver spare parts as negotiated.

Systems Engineering

The Contractor shall provide the personnel, equipment, and facilities necessary for all required systems engineering activities not specifically agreed to be provided by the Government at the time of negotiations. The systems engineering effort shall address all considerations necessary for the development of effort described above, including electrical, structural, mechanical, and data subsystems. The International System of Units (SI units) shall be the project standard and shall be used throughout the project. Engineering and manufacturing drawings using both English units and International System of Units (SI units) are acceptable for manufacturing purposes. All units shall be clearly marked in all documentation. The systems engineering effort includes understanding the customer's requirements; defining the system architecture; identifying, managing, validating, and verifying requirements; defining and managing interfaces; assessing environments; and maintaining technical budgets and margins.

Systems Engineering Management

The Contractor shall ensure necessary interaction within and among the SSCO, contractor, and subcontractor elements. The Contractor shall report systems engineering and technical issues as soon as they arise and shall give the Government complete access and insight into all systems engineering and technical activities and meetings. The Contractor shall prepare technical reports, responses to action items from design reviews, issue and reissue reports, and prepare and manage technical memoranda.

Requirements Identification and Management

The Contractor shall identify driving requirements to perform the effort described in Section 0 of this SOW and SSCO-RQMT-001064 Restore Robot Subsystem Requirements. The Contractor shall describe to the customer the impact of those requirements. The Contractor shall identify changes to requirements or baseline configuration that could significantly reduce cost or risk or increase performance. The Contractor shall analyze applicable documents, and derive and allocate lower-level requirements across the elements covered under this contract. This includes flow-down of system requirements into software functions and hardware implementations.

Interfaces and ICDs

The Contractor shall participate in developing interface specifications and documentation needed to ensure the design, development, integration, verification, and successful operation of the Robot Subsystem hardware. The contractor's systems engineering activities shall include elements and interfaces completely

under the contractor's control, as well as elements and interfaces not completely under the contractor's control.

The Contractor shall participate in the implementation of an overall interface configuration management and control program. This program shall apply to elements completely under the contractor's control, and to elements to which the contractor's deliverables interface. This shall include interfaces to all associated ground support equipment, interfaces unique to integration and test, and SSCO facilities. The Contractor shall submit inputs to the required ICDs.

Validation and Verification

Validation: During the design phase, the Contractor shall predict performance and perform trade studies to validate that the chosen design meets the requirements. The Contractor shall establish requirements tracing to ensure that the higher-level requirements flow to lower level requirements. The Contractor shall provide requirements tracking and verification data in AP233 format (ISO 10303).

Verification: The Contractor shall ensure that all requirements are verified.

Models: The Contractor shall develop, maintain, control, and use analytical models for purposes of pre-delivery performance prediction, design verification of all Robot Subsystem activities, and post-delivery and on going assessments as part of a Math Models Data Package (SE-02). The package shall provide the necessary traceability to all lower-level models. All model documentation in SE-02 shall be delivered in both electronic and paper formats. All model data files in SE-02 shall be delivered only in electronic format. All math models shall facilitate the rapid evaluation of design changes and shall support requirement flow-down and verification. The integrated modeling capability shall be used to optimize design margins and reduce costs.

As part of the Monthly Status Reports (PM-09), the Contractor shall provide the status of its modeling activities. This shall include the results of trade studies, requirements analyses, design verification analyses, model verifications, and the Math Models Data Package status.

The Contractor shall deliver the object and source codes, source code listings, and design details, algorithms, processes, flow charts, formulae, and related materials comprising complete integrated models and descriptions. The Contractor shall deliver comparable models and documentation for all supporting lower-level elements, subsystems, and components used in the system models. The Contractor shall deliver comparable models and documentation for all test beds. These deliverables (SE-02) shall enable the SSCO to reproduce, recreate, or recompile the software and reproduce, validate, and refine system analysis results.

SSCO Verification: The Contractor shall support SSCO-level systems analysis and requirements verification (acceptance tests). The Contractor shall coordinate its systems engineering activities with those of the SSCO and the other servicing element providers.

Technical Resources Budget Tracking

The Contractor shall generate electronic systems engineering databases that define resource (e.g., mass, power, etc.) allocations and maintain configuration control. The Contractor shall develop and institute a contingency policy that includes a phased-release plan for these resources as the design matures and is verified. The Contractor shall submit a Mass Properties Report (SE-03) during design reviews and update as required.

Technical Risk Management

The Contractor shall perform a technical risk analysis of the Robot Subsystem activities to identify potential problems, including the probability and timeframe in which the problems may occur, and the severity and cost impact of the consequences if they occur. The Contractor shall define and implement a process that continually assesses the risks to the Robot Subsystem operation, determines the relative threat of risks, implements strategies to mitigate significant risks, and measures the effectiveness of these strategies. This information shall be reported at monthly status reviews and during design reviews.

Safety and Quality Assurance

The Contractor shall develop and administer a safety and quality assurance program in accordance with NASA directives.

Safety

The Contractor shall define and implement the System Safety plan to ensure the identification and control of hazards during design, fabrication, test, transportation, ground activities, and Robot Subsystem operations. The Contractor shall interface with GSFC, and when appropriate, other agencies, to ensure Robot Subsystem safety requirements are met.

Quality Assurance

The Contractor shall develop and maintain a documented Quality Assurance Program. The Quality Assurance Program shall have sufficient staff and facilities to provide the required quality and reliability engineering, parts engineering, system safety, and materials control for the fabrication, integration, and verification testing (including test plans) of the Robot Subsystem hardware.

The Contractor shall provide the Government and its support contractors access to the reports, analyses, notebooks, and working papers of the staff performing the analyses and assessments [redacted].

Technology Development

The Contractor shall provide support for Robot Subsystem hardware, software, and GSE.

Hardware Design

The Contractor shall support the development of the concept and hardware designs for the Robot Subsystem. This shall include all aspects of the hardware such as:

- Mechanical and electrical systems
- Electromagnetic compatibility with GSE
- Power
- Command and data handling
- Communications
- Avionics interfaces
- Robotics and tools

Hardware Development

The Contractor shall design and fabricate electronic assemblies, harnesses, and ground support equipment. The Contractor shall purchase material and parts in support of their fabrication effort.

Robot Arm Subsystem Interfaces

The Contractor shall interface with all other parties supporting the Robot Subsystem operations through telecons and interface working groups. The Contractor shall prepare inputs for all interface control documents.

SCHEDULE

The Robot Subsystem support and associated risk reduction task shall be delivered [redacted].

REPORTING REQUIREMENTS

Weekly Reporting

The Contractor shall electronically submit and present (as necessary) Weekly Activity Reports (PM-08) containing:

- Summary of the activities for the week
- Brief status of each WBS element
- Schedule and schedule risk
- Highlight of technical issues, problems, and concerns
- Near-term milestones

Monthly Reporting

The Contractor shall submit Monthly Status Reports (PM-09) containing:

- Summary of the activities for the month
- Brief status of each WBS element
- Schedule and schedule risk
- Staffing
- Cost (monthly contractor financial management report)
- Highlight of technical issues, problems, and concerns
- Brief summary of plans for the following month
- Near-term (one-month) milestones for each WBS element

Appendix C: Statement of Work (SOW) for Restore-L Technology Development Testing

1.0 Restore-L technology Development Testing

1.1 Test Objectives – Overview of Flight & Ground Systems

The RESTORE-L office is performing a series of Technology Test Demonstrations, as defined in the RESTORE-L Technology Development Plan [redacted]. The primary purpose of these Test Demonstrations are to increase the technology readiness and mission readiness for the Restore RESTORE-L LEO servicing mission design

This Test Demonstration is a long term Restore System Development program, and thus is divided into multiple Phases, as defined later in this test plan.

1.2 Applicable Documents

Title
Restore Mission Level 2 Requirements
Restore Mission Development Technology Plan
Advanced Tool Drive System (ATDS) version 2.0

1.3 TRL advancement goal

The goal of this Test Demonstration series will be to advance the TRL of the Restore Payload elements when combined to function as an entire Restore-L Payload System. Thus, the emphasis of this Test Demonstration is to elevate the TRL of some of the Restore Payload System elements from TRL Level 4 to TRL Level 5 and eventually to TRL Level 6. This Test Demonstration is a long term Restore System Development program, and thus is divided into Phases in order to manage delivery goals and expectations. In early phases, the testing will primarily utilize Hardware Emulators (Prototypes with interface hardware in the loop). In later phases, the Test 6.5 Demonstration setup will be upgraded with Engineering Test Units (ETUs).

Table 2. Restore TRL Definitions

TRL	Hardware Definition	Software Definition
6	ETU tested with interface hardware in the loop in the flight environment	Tested on an ETU processor with interface hardware in the Loop
5	Prototype tested with interface hardware in the loop	Tested in prototype processor with interface hardware in the loop
4	Prototype tested at component level	Coded up in its destination language, unit tested in the workstation environment with simulated inputs
3	Prototype designed and analyzed	Algorithm description document written and implemented in any language
2	Thought of a way to do it	Thought of a way to do it
1	Realized need for the item and basic principles observed and reported	Realized need for the item and basic principles observed and reported

1.4 Test Phases / High Level Test Schedule

The Test Demonstration is a long term Restore System Development program, and thus is divided into Phases in order to manage delivery goals and expectations. The Test Phases are defined as follows:

SSCO Technology Development System Tests

Ref. #	Name	Objectives	Test Venue	Start Date	Completion Date	Status
System Level Prototype Tests (TRL 4 and 5)						
System Level EDU Tests (TRL 6)						
6.01a	Capture ESD Mitigation Testing	1) Obtain design requirements of the attachment and equalization system 2) Evaluate concepts to equalize charges between two spacecrafts 3) Perform reliability for selected bleeding mechanism Test impact of no discharge mitigation system	NRL	Nov-12	Dec-12	Complete
6.01b	ESD gripper tests		TBD		TBD	Need Plan
6.02	Robot FSW HWIL Testing	Robot FSW on a spaceflight processor	GSFC		Feb-17	Underway
6.02a	Robot FSW HWIL Point-to-point	1) Command industrial robot from SpaceCube emulator to perform the simplest robot motion	GSFC		Nov-15	Complete
6.02b	Robot FSW Simulated Autonomous Capture	1) Robot flight software required for nominal autonomous capture implemented in SpaceCube emulator 2) Test runs completed with either industrial or EDU robot arm	GSFC		Jun-16	Planning
6.02c	Full Robot FSW functionality	1) SpaceCube EDU hosts all robot flight software functionality 2) Test runs completed with either industrial or EDU robot arm 3) Includes all functionality -auto capture, servicing, collision avoidance, etc	GSFC		Feb-17	Planning
6.03a	PTM EDU Functional Test	1) Test Gfe module and PCV (what's an PCV?) 2) Test PTM fluid transfer (referee and hypergolf) with EDU pumps, bellows, flow meter, valves, ENT, etc at various pressure and flow conditions 3) Test timing and subroutines/feedback loops in a Labview based PTCE emulator 4) validate PTS fluid/gas analysis	KSC		Jul-13	Complete
6.03b	HMS EDU Functional Test	1) EDU hose box hose deployment tests 2) Launch lock testing Objective 3) Vibe and termal vaccum of hose box and hose assy	KSC		Missing	Underway
6.04	Robot Camera Perf Test	Characterize and mature capture machine vision related hardware and algorithms in various lighting conditions	GSFC/B3	Jan-16	TBD	Underway
6.04a	RAP Performance Test	Characterize Robot Arm Position (RAP) algorithm performance with ATD5 camera HWIL and various lighting conditions			May-16	Underway
6.04b	RPO Synthetic Imagery Test				TBD	
6.04c	Camera Data Through CFTM and Robot Arm Flex Harnesses				TBD	
6.04d	AGC Test (needed before RPO vis cams)				TBD	
	RPO Vis cam decision (to unify procurement)				TBD	
6.09	Hose Manipulation Trajectory and Loads Test (PM 2)	Characterize Hose trajectories to investigate potential Hose load concerns in test 6.5	GSFC/Z7N		May-15	Complete

SSCO Technology Development System Tests

Ref. #	Name	Objectives	Test Venue	Start Date	Completion Date	Status
ZeroG3	Hose Zero G Testing	1) Static behavior test - how to protect Hose from load limits when in Zero G environment 2) Dynamic Behavior Tests - How does the Hose move in space, use for model correlation	JSC	Jun-13	Jun-15	Complete
6.4Sa	Verification of Refueling Hose Loads for Test 6.5 Payload Configuration	Checkout 6.5 Hose trajectories to investigate potential Hose load concerns. Verify Phase 1 results of using Robot FTS to monitor Hose loads for 6.5	GSFC/27N		May-15	Complete
6.4Sb	Verification of Refueling Hose Loads for Test 6.5 Payload Configuration	Checkout 6.5 Hose trajectories to investigate potential Hose load concerns. Verify Phase 1 results of using Robot FTS to monitor Hose loads for 6.5	GSFC/27N		May-15	Complete
6.5	Refueling End-to-End Test	Demonstrate end-to-end robotic refueling of a representative client satellite with the Restore servicing payload design	GSFC/29-150	Sep-14	TBD	Underway
6.5 - I	Post-Berthing Visual Client Survey	1) Eval of the VSS system 2) Early looks at interfaces among Avionics, Ground, and VSS	GSFC (29/150)	Oct-15	TBD	Underway
6.5 - II	Refueling demonstration		GSFC (29/150)	Jan-16	TBD	
6.5 - III	Blanket Manipulation		GSFC (29/150)	Mar-16	TBD	
6.5 - IV	ETU Tool Development and checkout with ETU Restore Robot Arm and ETU Restore Avionics		GSFC (29/150)	TBD	TBD	
6.5 - V	Operations/Team High fidelity training		GSFC (29/150)	TBD	TBD	
6.6	CBS Berthing Testing	Test Prototype CBS with various client spacecraft with representative mass and CGs and characterize CBS performance	GSFC/16W-200	Jun-15	TBD	Underway
6.6.a	Bread Board design concept of CBS Motor design and Electronic drive box	Prove out that we can drive contact points of the Chuck device simultaneously so that the Client Space Craft (CSC) will be centered in the CBS with out pushing it across palm surface.	GSFC	Jun-15	Mar-16	Underway
6.6.b	CBS Concept Testing	1. Prove that the Chuck device can clamp onto various mannon ring sizes and profiles. 2. Prove that the CBS clamps with appropriate forces.	GSFC	Mar-16	TBD	
6.6.c.1	Free Space evaluation of Robot Arm system with CBS with GOES-12 as Client	Free Space studies to prove out Robot Arm with ATDS and Gripper moving Ring into CBS and ability for Arms system to rotate CSC within a capture box of CBS	GSFC	TBD	TBD	
6.6.c.2	Free Space evaluation of Robot Arm system with CBS with TBD Client		GSFC	TBD	TBD	
6.6.d	Adams evaluation of Robot Arm system with CBS	Adams contact dynamics analytical force and time studies	GSFC	TBD	TBD	

SSCO Technology Development System Tests

Ref. #	Name	Objectives	Test Venue	Start Date	Completion Date	Status	Test Lead(s)	Report or Memo
6.6.e	EDU CBS Testing with Gripper This test was in question as to the need of it. Maybe this test should be conducted by Robot subsystem.	1. Prove that Robot Arm System, with Gripper, can move the marman rings to the CBS and have the Chuck device close. 2. Have the CBS loosen its grip on the marman ring and the Robot, with gripper, has the ability to rotate the ring/CSC without falling out of a CBS capture box. 3. Prove out, potential, rotational capability of CBS mechanism instead of Robot arm system doing the rotation. 4. Provide RDT with load forces on Robot.	GSFC/27N	TBD	TBD		Hanyok?	
6.07	End-to-End System Autonomous Capture Tests		GSFC/29-150		TBD	Underway	Gardel/ Keith	
6.07a	Capture tests with prototype hardware controlled by workstations	A1) Robot closed loop using robot machine vision on ML507 A2) VDSU in the loop A3) Rotopod closed-loop RPO control of intra-vehicle relative motion, including contact dynamics A4) All RPO in ML507 A5) VDSU emulator w/ Restore Payload Data formatting	GSFC/29-151		TBD	Underway		
6.07b	Captures with all capture FSW on SpaceCube Emulator	B1) B2)	GSFC/29-152		TBD	Planning		
6.07c	Full EDU System Autonomous Capture	C1) C2)	GSFC/29-153		TBD	Planning		
6.07q	POTS Proximity Operations and Capture Test	Q1) Full "end-to-end" autonomous capture from 1/10th scale inspection to grasp Q2) Demonstrate autonomous aborts for various system faults	NRL		Cancel?	Cancel?		
6.08	Restore RPO Sensor EDU Characterization	Test RPO sensors over full range of motion (~2Km - ~15m)			TBD		Keith	
6.09					Unused			
6.10					Unused			
6.11	Remote Robotic Oxidizer Transfer Test (RROxiTT)	1) Flow NTO at flight like pressures using flight like equipment 2) Show that robotic mate and transfer Ops are leak free 3) Teleoperate the Robot with Key Elements of the Restore Robot Control Station 4) Advance TRL with NT, QD, and Robot TeleOp with NTO 5) Will not do vampire mode or pressurization during this hazardous test	KSC/PHSF (w/GSFC teleoperator)		Mar-14	Complete	Riley / Coll / Snyder	
6.12	PTA EDU Hydrazine Transfer Test	1) Test GHe module and FCV (what's an FCV?) 2) Test PTM fluid transfer (reference and hypergol?) with EDU pumps, bellows, flow meter, valves, ERT, etc at various pressure and flow conditions 3) Test timing and subroutines/feedback loops in a Labview based PTCE emulator 4) validate PTS fluid/gas analysis			Cancel?	Cancel?		

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1.5 Data Collection and Storage

All Operational test telemetry and test video data transmitted from the Servicing Payload Deck shall be time stamped, collected and stored electronically. Retrieval access to collected data shall be provided upon request. Additional 'witness' camera views taken in 29/150 shall be time stamped, collected and stored electronically in the 29/150 Robotic Facility.

1.6 PASS/FAIL Criteria

All tasks shall be performed until the test director, responsible engineers, and project management agree that the task has been successfully performed in accordance with the Restore-L conops definition for nominal operations. In the event that off nominal conditions/results occur, the team shall either 1) Back up to the last valid nominal point of execution and repeat the activity until an understanding/resolution is determined and a return to nominal execution is able to proceed, or 2) Alter the Restore-L conops definition for nominal operations based on the new test information.

1.7 Test Repeat Strategy

If required, test repeats will be performed after a review of the test data by a decision of the test director, responsible engineers, and project management.

1.8 Test Close-Out

After all parties have had an opportunity to review the data, test close-out may be performed with the concurrence of the test director, test conductor, and responsible engineers. A test report for each tool/task evaluation will be generated within 45 days of the completion of each tool/task evaluation performed.

Omnibus Multidiscipline Engineering Services (OMES)

Task Order 72 - JPSS-2 Spectral-Radiometric Calibration

Task Value: $359K

Scope of Work:

The Joint Polar Satellite System (JPSS) is the Nation's next generation of polar-orbiting environmental satellites. JPSS is a collaborative effort between NOAA and NASA, and represents significant technological and scientific advancements in severe weather prediction and environmental monitoring and will help advance weather, climate, environmental and oceanographic science. The Visible Infrared Radiometer Suite will be an instrument on board JPSS-2, and will require high accuracy absolute spectral-radiometric calibration. This calibration will be performed by GSFC and the National Institute of Standards and Technology (NIST), and will make use of the SIRCUS calibration technique developed by NIST and successfully used with previous spacecraft, including JPSS-1. Widely tunable, high power laser sources are central to the SIRCUS technique, several of which are currently under development at GSFC and are intended for use with JPSS-2 calibration in fiscal year 2016.

Technical Requirements

The contractor shall provide general engineering support in the following areas:

1. SIRCUS tunable laser calibration system operation
    a. Operate SIRCUS laser system as required for instrument calibration tests.
    b. Keep [redacted] informed of any required troubleshooting, maintenance, or alignment activities to maintain performance of the system.
2. SIRCUS tunable laser development
    a. Addition of second optical parametric oscillator to cover 550 – 700 nm and 1100 – 1400 nm wavelength range.
    b. Addition of SWIR wavelengths to cover 1400 – 2200 nm.
    c. Improve portability, ease of use, and stability to meet JPSS-2 calibration requirements.
3. Support all activities related to [redacted] optical components. Contractor shall perform [redacted] the following activities:
    a. [redacted].
    b. Provide general technical oversight of component fabrication as needed.
    c. Identify and specify optical and opto-mechanical components as needed.
    d. Work in collaboration with Code 500 for the machining of parts as needed.
    e. [redacted].

f. Receive and inspect procured components working in close communication with the GSFC QA counterpart. Prepare documentation for Government Property Transfer.

Travel

Possible travel in support of JPSS-2 calibration activities [redacted] in El Segundo, CA third quarter FY 2016. Expected duration of two weeks.

Period of Performance

10/1/2015 – 9/30/2016

[redacted]

[redacted]

Deliverables

Engineering Document		Due Date
Qty	**Hardware Items**	**Deliver Date**
	N/A	
Task Management Deliverable Event/Item		**Due**
Technical Progress Reports and 533 Input Data Sheets		15th of the month
Final Task Report		15 days prior to task end date

Omnibus Multidiscipline Engineering Services (OMES)

Task Order 73 - Asteroid Redirect Mission

Task Value: $2.15M

Scope of Work:

I. Overview of the Asteroid Redirect Mission

The Asteroid Redirect Mission (ARM) is a capabilities demonstration mission that will advance the synergy between robotic and manned space technologies as part of NASA's plan to develop and implement the necessary tools for human exploration of the Martian system. ARM will provide an initial demonstration of the technology necessary for long-duration, human-scale systems operating in deep space including sensor suites and proximity operations, enhanced interaction with low-G targets, long-duration, high-powered solar-electric propulsion (SEP), and in-space extra-vehicular activity (EVA) operations.

The Asteroid Redirect Mission is comprised of three components:

Identify: Since the announcement of the Asteroid Initiative in 2013, NASA's Near-Earth Object Observation Program has catalogued more than 1,000 new near-Earth asteroids. Of those identified, four could be good candidates for ARM. NASA will characterize the velocity, orbit, size and spin of all candidate asteroids before deciding on the target asteroid for the ARM mission in no earlier than 2019.

Redirect: The robotic component of ARM, the Asteroid Robotic Redirect Mission (ARRM), is a cross-agency collaboration to land on a large near-Earth asteroid, collect an approximately 4-m boulder from its surface, and redirect the boulder into a stable orbit around the moon. The ARRM spacecraft will include a launch adapter, SEP module, mission module, and capture module. The capture module, comprised of two robotic arms outfitted with grappling tools, will grasp the boulder while it is removed from the surface of the asteroid during a fully autonomous landing, collection, and lift-off sequence. The spacecraft will image and characterize the asteroid boulder and demonstrate planetary defense techniques before transporting the boulder to a stable lunar orbit, where it can be further analyzed both by robotic probes and by a future manned mission.

Explore: The boulder will be in trans-lunar orbit and available for crewed exploration by the mid-2020's. NASA's Orion spacecraft will launch on the agency's Space Launch System rocket, carrying astronauts on a mission to rendezvous with and explore the asteroid mass. The current concept for the crewed mission component of ARM is a two-astronaut, 24-25 day mission. During EVA, the crew will interact with the asteroid boulder and take samples for return to Earth.

This Statement of Work (SOW) specifies work to be done and services to be provided in support of the Satellite Servicing Capabilities Office (SSCO) Asteroid Robotic Redirect Mission. This task provides support of all levels of ARRM system and subsystem engineering, technology development, system design, documentation, fabrication, integration and test, ground system development, and operations. It is organized to match the ARRM Work Breakdown Structure (WBS) Elements, with subtasks generally aligned with anticipated ARRM WBS Elements. Figure 1 illustrates the ARRM WBS elements, and their tie-back to the SSCO (Code 408) matrix organization.

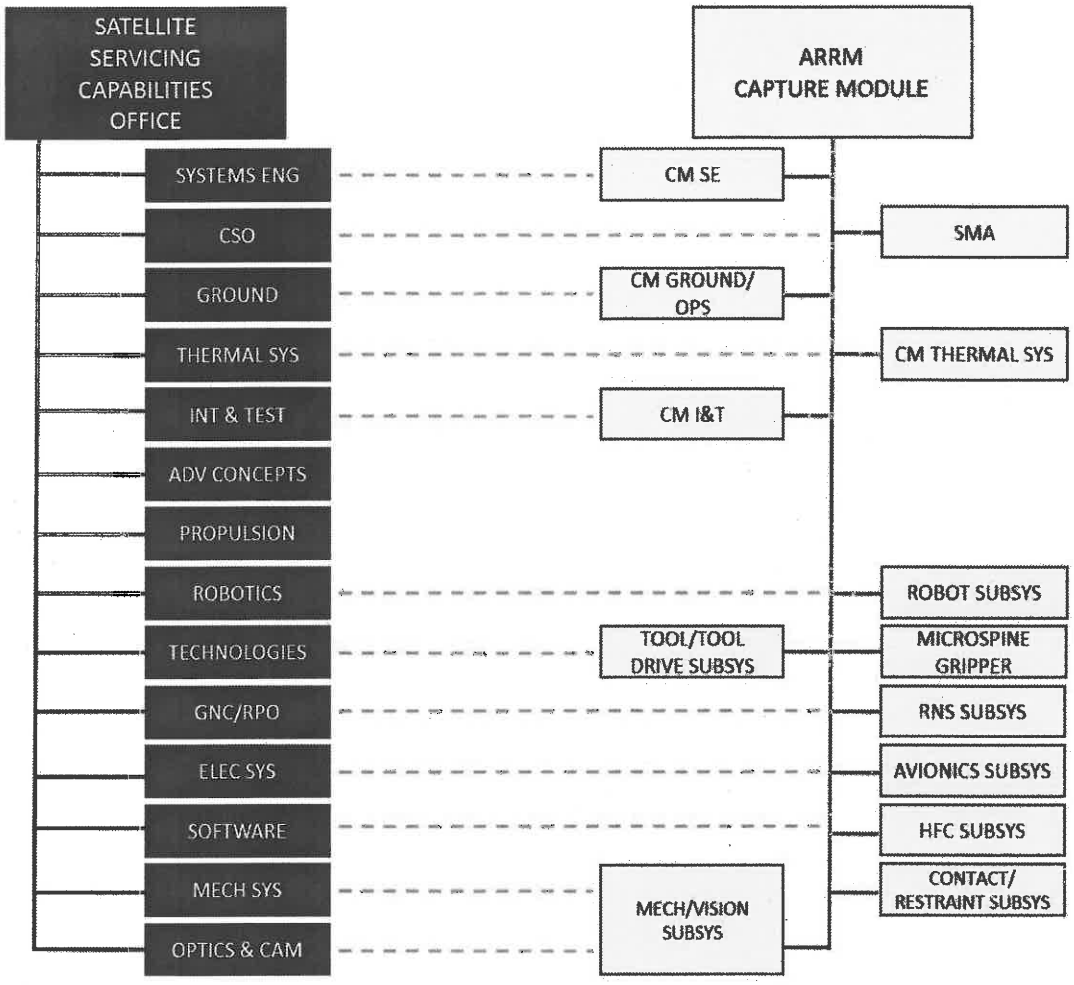

Figure 1 – Subtask breakdown

Many ARM technologies are directly applicable to Restore-L. This task includes all efforts applicable only to the Asteroid Redirect Mission. Efforts applicable to both Restore-L and ARM are covered under a separate task order. ARM requirements will be incorporated into Restore-L component-level specifications to allow use of the components in both missions without redesign. Restore-L design reviews will include summaries of ARM requirements and vice versa.

II. Summary of Work

The sections below document anticipated ARRM efforts and schedule in FY16. As described in the *Deliverable Items and Schedule* section below [redacted]

[redacted] The remainder of this section is included for informational purposes only.

Project Management Support

The Contractor shall provide SSCO with appropriate manpower to support key system and subsystem management positions, as described below:

- ARM Deputy Robot Subsystem Manager (WBS 5.04)
- ARM Tool Drive Subsystem Deputy Manager (WBS 5.05)
- ARM Capture Module (CAPM) Avionics Subsystem Manager (WBS 5.07)
- ARM Capture Module (CAPM) Mechanical Subsystem Manager (WBS 5.09)

System Engineering and Documentation support

ARRM is a Phase A mission managed by the Jet Propulsion Laborator (JPL). The flight element includes two major components: a spacecraft bus to be procured by JPL (with support from Glenn Research Center), and a Capture Module (CAPM) managed, built, and integrated by GSFC. GSFC also provides the system engineering phase lead for the asteroid proximity operations phase. This task includes system engineering and development of documentation for the ARM and CAPM as defined in NPR 7120.5 and NPR 7123.1, with tailoring as defined in the ARRM Project Implementation Plan and System Engineering Development Plan.

System engineering support includes but is not limited to structural, mechanical, electrical, thermal, data systems, environments, reliability, risk tracking, system architecture definition, contamination etc.

Required documentation includes but is not limited to: 1) mission requirements at all levels; 2) mission concept of operations; 3) sub-system specifications; 4) technology development plans; 5) technology development test reports; 6) interface control documents; 7) integration and test

procedures and reports; 8) validation and verification and plans and reports; 9) analysis, drawings and models; 9) risk management plans and assessments; etc.

Hardware and Software Design, Analysis, Fabrication, and Test

Hardware and software will be developed as required to support the system and subsystem Asteroid Robotic Redirection Mission schedule shown in Figure 2.

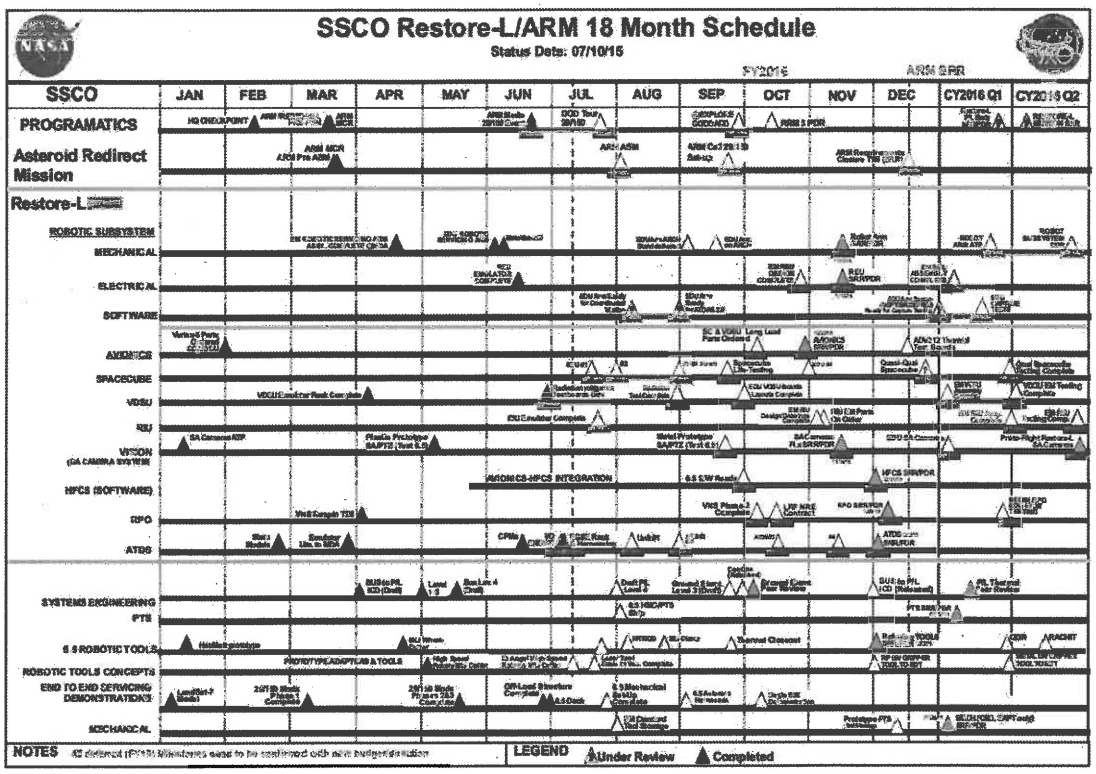

Figure 2 – Task 73 POP Summary Schedule; Restore-L schedule included for related synergy data

III. Period of Performance

The period of performance shall be November 1, 2015 through October 31, 2016.

IV. Subtask Description

Staffing, fabrication, and procurement to achieve the ARRM Mission objectives in the *Summary of Work* section shall be proposed and reported in a single subtask, for now. The subtasks shown in Table 1 are for reference only.

Table 1 - Subtask Descriptions (for reference only, subtask breakdown will be implemented in a future modification of this task order)

OMES Subtask Number	WBS Element	Subtask Description
101	Reserved (JPL ARRM Mgmt)	*Not funded in this task modification.*
201	Reserved (JPL ARRM Sys Eng)	*Not funded in this task modification.*
301	Reserved (JPL S&MA)	*Not funded in this task modification.*
401	Reserved	*Not funded in this task modification.*
	Capture Module	
501	Project Management	Includes management of the ARRM project.
502	System Engineering	Includes support of the CAPM System Manager.
521	GSFC Sys Eng	Includes support of the Capture Module Systems Eng. Responsible Engineer.
522	LaRC Sys Eng	Includes support of the Capture Module LaRFC Systems Eng. Responsible Engineer.
523	Thermal	Includes support of the Capture Module Thermal Responsible Engineer.
503	CAPM Safety & Mission Assurance	Includes support of the CAPM Safety & Mission Assurance Manager.
	Robot Subsystem	
541	Robot System Eng	includes support of the ARRM Robot Subsystem Manager.
542	Reserved (Robot Arm)	*Not funded in this task modification.*
543	Reserved (REU)	*Not funded in this task modification.*
544	Reserved (Robot FSW)	*Not funded in this task modification.*
	Tools and Tool Drive	
551	ATDS	Includes support of the ARRM Tool Drive Manager.
556	Tools	Includes support of the ARRM Tools Manager.
557	JPL Microspine	Includes support of the Microspline Responsible Engineer.
	Asteroid Ops GNC	
561	GSFC RNS	Includes support of the ARRM Operations and GNC Manager.
562	Reserved (RPO FSW)	*Not funded in this task modification.*
563	Reserved (RPO Hardware)	*Not funded in this task modification.*
564	Reserved (JPL Control)	*Not funded in this task modification.*
	CM Avionics Subsystem	
571	CM Avionics Sys Eng	Includes support of the ARRM Avionics Subsystem Manager.
572	SpaceCube	Includes support of the SpaceCube Responsible Engineer.
573	RIU	Includes support of the RIU Responsible Engineer.
574	VDSU	Includes support of the VDSU Responsible Engineer.
575	Harness	Includes support of the Harness Responsible Engineer.
581	Hybrid Flight Computing	Includes support of the ARRM HFCS Manager.
	Mechanical Subsystem	
591	CM Structure & System Eng	Includes support of the ARRM Mechanical Subsystem Manager.
592	Tool Stowage Mechanism	Includes support of the Tools Stowage Responsible Engineer.
593	Reserved (Not used)	*Not funded in this task modification.*
	I&T	
510	Capture Module I&T	Includes support of the Capture Module I&T Manager.
513	Vehicle I&T	Includes support of the ARRM Vehicle I&T Manager.
511	Vision	Includes support of the ARRM Vision Subsystem Manager.
512	CRS-LEGS	Includes support of the CRS-LEGS Manager.
601	Spacecraft Bus	Includes support of the ARRM Spacecraft Bus Manager.
701	Reserved (Launch Vehicle)	*Not funded in this task modification.*
801	Reserved (Operations)	*Not funded in this task modification.*
901	Ground	Includes support of the ARRM Ground System and Operations Manager.
10	Reserved (JPL I&T)	*Not funded in this task modification.*

V. Deliverable Items and Schedules

Deliverables for these tasks include reports and presentations describing system trade studies, design, participation in component, subsystem, and system-level reviews, ground tests, etc, algorithm mathematical specifications, analysis and test results, ground system software deliveries, and delivery documentation [redacted]. Deliverables include the above items [redacted], all of which will be produced by multi-disciplinary team from multiple contracting sources, and thus not a direct deliverable from this Task. Specific deliverables for this task are monthly progress reports delivered [redacted] on the 15th of each month.

VI. Management Approach

a. Staff Allocation, Expertise, and Skill Mix

The contractor shall staff this work item with the appropriate skill mix and staffing level for the work. Some manpower positions may be filled with individuals possessing an active security clearance.

b. Configuration Management

Systems and documents will be covered under the Satellite Servicing Capabilities Office Configuration Management Plan.

c. Facilities

Appropriate Information Technology devices to support the analyses, specification development, and report development are required. It shall be the contractor's responsibility to provide and set up local workstations and network connections at the contractor's off-site facilities as required, and to install any required tools and utilities on the contractor's equipment.

d. Risk Management and Best Practices

The contractor shall manage schedule, cost, and technical risk through monitoring and reporting of progress, identifying issues well in advance of negative consequences, recommending corrective action [redacted], and implementing corrective actions with the compliance [redacted].

e. Performance Metrics

The [redacted] will evaluate the work performed for this task based on technical merit. The [redacted] will utilize detailed performance metrics that reflect the contractor's performance in meeting research analysis, specific mission requirements, deliverables and delivery schedule, and the contractor's cost. The [redacted] technical evaluation of the task performance will be a subjective combination of performance metrics, technical quality of deliverables, cost control, significant events, innovations and meeting requirements set forth in the SOW. The primary performance tracking mechanism for this task shall be via the ARRM JIRA issue tracking system.

f. Government Furnished Facilities, Equipment, Software and Other Resources

The Government will provide account and passwords to government-furnished workstations where existing versions of various relevant software packages shall be maintained. It shall be the contractor's responsibility to complete any GSFC required security-related training courses.

VII. Travel

Non-local travel is required for this task. Travel requirements may include, but are not limited to, Kennedy Space Center, Johnson Space Center, West Virginia Robotics Lab, Langley Research Center, Jet Propulsion Laboratory, and ARRM partner-site and vender-site visits.

VIII. Work Location

This work shall be performed primarily on-site at the Goddard Space Flight Center, but the contractor may be required to perform some work at the contractor's facility, at the Naval Research Laboratory, and at several other NASA and contractor test facilities.

IX. Reporting Requirements

The contractor shall report status in person or via teleconference [redacted] on a monthly basis. Reports may include informal presentation of interim results, status of development activities, and action item status. The contractor shall also support [redacted] in the preparation of status reviews for internal and external funding agencies. The contractor shall comply with any and all additional requests for status meetings and reports. The contractor shall deliver all documents in portable document format (PDF) electronic form [redacted].

X. Security Requirements

This task shall comply with IT security requirements as documented in the Servicing Study IT security plan for all systems.

XI. Rights

This SOW shall adhere to the RIGHTS IN DATA – special works (FAR 52.227-17) as modified by NFS 1852.227-17.

Omnibus Multidiscipline Engineering Services (OMES)

Task Order 76 - JPSS/Polar Follow-On (PFO) Program Office Study Manager Support

Performance Period: 15 months

Task Value: $745K

Scope of Work:

This task is to provide engineering support services in accordance the TOMS SOW to the JPSS/PFO Program in the areas of program support, including [redacted] preparations for reviews and presentations, support mission planning for JPSS-2/3/4, develop and support schedule reviews, support technical reviews, and provide weekly report

The contractor shall provide cognizant engineering support to:

1. Provide Technical Management support to the JPSS Program Office [redacted]
    1) Support mission planning for JPSS-2/3/4.
    2) Develop and support schedule reviews.
2. Support JPSS/PFO Program preparations for and conduct of reviews
    a) Work with JPSS/PFO Program to identity the content of the reviews
    b) Provide programmatic insight into the JPSS/PFO integrated schedule
    c) Provide programmatic insight into JPSS/PFO strategic planning
3. Perform assessment of capabilities gap between JPSS1 and JPSS2 as well as the ground system capabilities and provide recommendations for and support the implementation of the path forward for JPSS2 and the ground system.
4. Perform assessment of the program plan for JPSS 2, JPSS3, and JPSS4 and provide recommendation for implementation as well as support the program plan implementation
5. Identify, prepare, and maintain JPSS/PFO Program documentations as required by NPR 7120.5E.
6. Document work performed and assist [redacted] to develop technical reports and presentations
7. Provide programmatic insight to PFO planning and advanced concept developments.
    a) Work with PFO Strategic Planning and Advanced Concept team in developing post PFO-missions and milestones
8. Support new technology development for next generation JPSS/PFO sensors
9. Support JPSS/PFO meetings as required
10. Support JPSS/PFO Program studies for advanced concepts development
11. Support the Strategic Planning and Advanced Concept Office to: review technical documentation; prepare programmatic and technical documents and briefs; convene and

participate in special studies and review boards; [redacted] program planning and advanced concepts

12. Support JPSS Program Office for reviews and document preparations [redacted]

Travel:
The contractor shall plan for approximately 1 trip per month, total no more than 7 trips, to Chandler, AZ. The duration for each trip is approximately 4 days.

Additionally, a contractor may be required to travel 2 to 3 times a year.

Deliverables:

1. Weekly/Monthly Status Report
    a) The reports will briefly status issues, action items, trips, progress of ongoing assignments and priorities for next month. Contractor will coordinate and prepare content.
2. Trip Reports/Meeting minutes [redacted]
3. Technical reports and analyses [redacted] by the JPSS Program Office, due dates to be coordinated depending on the content.
4. Documents and products [redacted]
5. One of kind documentation [redacted]