

ATTACHMENT A

# FLIGHT DYNAMICS SUPPORT SERVICES II

## STATEMENT OF WORK

FEBRUARY 2014

ATTACHMENT A

**Table of Contents**

**I. GENERAL INFORMATION .....3**

**II. CONTRACT REQUIREMENTS .....4**

A. SECTION 508 OF THE REHABILITATION ACT.....4

B. SOFTWARE ENGINEERING REQUIREMENTS .....4

C. WORK BREAKDOWN STRUCTURE.....5

1.0 Flight Dynamics Facility Operations .....5

1.1 Operations Support ..... 6

1.1.1 Orbit Determination and Analysis ..... 6

1.1.2 Tracking Data Evaluation and Calibration..... 7

1.1.3 Acquisition Data ..... 7

1.1.4 Mission Planning and Scheduling Products ..... 7

1.1.5 Maneuver Planning Support ..... 8

1.1.6 Human Space Flight Support ..... 8

1.1.7 Expendable Launch Vehicle (ELV) Support..... 8

1.1.8 USSTRATCOM Liaison..... 8

1.2 Flight Dynamics Systems Engineering ..... 9

1.2.1 FDF System Engineering ..... 9

1.2.2 System Facilities Sustaining Engineering ..... 10

1.2.3 Model Maintenance ..... 11

1.2.4 Automation Techniques ..... 11

1.3 Conjunction Assessment ..... 11

2.0 Flight Dynamics Analysis ..... 12

2.1 Flight Project Support ..... 12

2.1.1 Navigation Analysis..... 12

2.1.2 Mission Design ..... 13

2.1.3 Maneuver Planning ..... 13

2.1.4 Attitude Determination and Control Analysis..... 13

2.1.5 Ground System Development ..... 13

2.2 Technology ..... 13

2.2.1 Advanced Navigation Techniques ..... 14

2.2.2 Advanced Mission Design Techniques ..... 15

2.2.3 Advanced Attitude Techniques ..... 15

2.2.4 Formation Flying Techniques ..... 15

2.2.5 Commercial-Off-The-Shelf (COTS) Evaluation..... 15

2.2.6 CAVE Advanced Visualization Environment (CAVE) ..... 15

2.2.7 Conjunction Assessment Risk Analysis..... 16

2.2.8 Relative Navigation System Development ..... 16

**III. DATA ITEM DESCRIPTIONS.....17**

SOFTWARE MANAGEMENT PLAN..... 17

SOFTWARE CONFIGURATION MANAGEMENT PLAN ..... 20

SOFTWARE ASSURANCE PLAN..... 21

ATTACHMENT A

## I. General Information

The Navigation and Mission Design Branch (NMDB) and the Attitude Control Systems Engineering Branch (ACSEB) within the Mission Engineering and Systems Analysis (MESA) Division at Goddard Space Flight Center (GSFC) are responsible for providing analytic and operational expertise for orbit and attitude systems, dynamics modeling, control analyses, and estimation and simulation of space vehicles. The branches create and maintain state-of-the-art analysis tools for mission design, trajectory optimization, orbit analysis, navigation, attitude determination, and controls analysis. The branches also provide the expertise to support a wide range of flight dynamics services, such as spacecraft mission design, on-orbit sensor calibration, launch support, and orbit operations. An active technology development program is maintained, with special emphasis on developing new techniques and algorithms for autonomous orbit/attitude systems and advanced approaches for trajectory design. Specific areas of expertise resident in the branches are:

- Trajectory analysis and control design
- Mission operations
- Mission design
- Orbit estimation techniques
- Constellation analysis
- Flight dynamics model development
- Flight dynamics ground and flight system development
- Ground attitude determination

The NMDB flight dynamics support services provide for the planning, designing, implementation, enhancement, evaluation, integration, testing and conducting of the flight dynamics services and systems provided at GSFC. The flight dynamics disciplines include spacecraft navigation (orbit determination), trajectory control, mission design, attitude determination, attitude dynamics and attitude control. Unique mission support and network services are also provided. Flight dynamics mission support efforts involve the determination of mission flight dynamics requirements and the planning necessary to satisfy the mission/project needs. Technology development is performed in the areas of navigation, trajectory design and flight dynamics automation. Flight regimes supported include single satellite and satellite formations in low-Earth, high-Earth, gravity assist, libration point, non-Earth planetary and interplanetary orbit. Operational facility modernization planning, development, implementation and sustaining services are also provided.

Operations support is primarily provided through the NMDB's Flight Dynamics Facility (FDF). In 2013, this facility will support flight dynamics computations for more than twenty spacecraft. Operational support includes orbit determination, acquisition data generation for the space and ground networks, tracking data evaluation, calibration and maneuver planning support. The FDF also supports Expendable Launch Vehicle (ELV) operations and International Space Station (ISS) orbit determination.

## ATTACHMENT A

The FDF is a multi-mission operations facility that is located on the second floor, north wing in Building 28 at the GSFC. The FDF consists of a general operations area, a mission operations area, and a computer room. The general operations area covers approximately 1,320 square feet, the mission operations area covers approximately 2,660 square feet, and the computer room covers approximately 3,360 square feet. Office space to house support personnel is provided adjacent to the FDF and is considered part of the facility. Additionally, there are two conference rooms that are part of the FDF area. The FDF has approximately 100 computers that are used for operations support in a virtualized environment. These computers consist of server class machines that provide data storage and processing, external communications, and mission support and workstation class machines that are used for critical and mission support. These machines use Windows, UNIX and LINUX operating systems.

This Statement of Work (SOW) defines the effort required to provide flight dynamics analysis, operations, system development and technology support for the NMDB and ACSEB.

## II. Contract Requirements

### A. Section 508 of the Rehabilitation Act

In order to comply with the Section 508 Electronic and Information Technology Accessibility Standards, the contractor shall perform all work required under this contract in compliance with the following technical standards delineated in Code of Federal Regulations (CFR) Title 36:

- 1194.21 Software Applications and Operating Systems
- 1194.22 Web-based Intranet and Internet Information and Applications
- 1194.23 Telecommunications Products
- 1194.24 Video and Multimedia Products
- 1194.25 Self Contained, Closed Products
- 1194.26 Desktop and Portable Computers

### B. Software Engineering Requirements

Approximately 40 percent of the Work Breakdown Structure in this SOW is related to software services including software modification, development, and maintenance activities and is subject to compliance with NASA Procedural Requirements, NPR 7150.2A, NASA Software Engineering Requirements.

The contractor shall develop the following software plans (stand-alone or condensed into one or more documents) that meet the required content described in Section III, Data Item Descriptions. These software plans will be initiated by contract task order and submitted by the contractor for approval by NASA. After NASA approval, the software plans shall become contractually binding for all software activities in the Work Breakdown Structure tasks of this SOW:

ATTACHMENT A

- Software Development or Management Plan
- Software Configuration Management Plan
- Software Assurance Plan.

### **C. Work Breakdown Structure**

The Work Breakdown Structure (WBS) for the SOW is listed below.

#### 1.0 Flight Dynamics Operations

##### 1.1 Operations Support

- 1.1.1 Orbit Determination and Analysis
- 1.1.2 Tracking Data Evaluation and Calibration
- 1.1.3 Acquisition Data
- 1.1.4 Mission Planning and Scheduling Products
- 1.1.5 Maneuver Planning Support
- 1.1.6 Human Space Flight Support
- 1.1.7 Expendable Launch Vehicle Support
- 1.1.8 USSTRATCOM Liaison

##### 1.2 Flight Dynamics System Engineering

- 1.2.1 FDF System Engineering
- 1.2.2 System Facilities Sustaining Engineering
- 1.2.3 Model Maintenance
- 1.2.4 Automation Techniques

##### 1.3 Conjunction Assessment

#### 2.0 Flight Dynamics Analysis

##### 2.1 Flight Project Support

- 2.1.1 Navigation Analysis
- 2.1.2 Mission Design
- 2.1.3 Maneuver Planning
- 2.1.4 Attitude Determination and Control Analysis
- 2.1.5 Ground System Development

##### 2.2 Technology

- 2.2.1 Advanced Navigation Techniques
- 2.2.2 Advanced Mission Design Techniques
- 2.2.3 Advanced Attitude Techniques
- 2.2.4 Formation Flying Techniques
- 2.2.5 Commercial-Off-The-Shelf (COTS) Evaluation
- 2.2.6 CAVE Advanced Visualization Environment
- 2.2.7 Conjunction Assessment Risk Analysis
- 2.2.8 Relative Navigation System Development

### **1.0 Flight Dynamics Facility Operations**

## ATTACHMENT A

The contractor shall provide analytic and operational support for spacecraft orbit determination; trajectory control; product generation; acquisition data generation and transmission; and tracking data evaluation and testing. The contractor shall support trajectory determination, monitoring, and network support operations for crewed flight and expendable launch vehicles (ELV). The responsibilities include a combination of analytical tasks, critical operations support including launch and early orbit checkout, and routine production activities. Operations support is primarily conducted in the FDF. The contractor shall permit Government insight of all operational support, product development, test and maintenance activities. The contractor shall permit Government personnel electronic access to documentation generated for or related to flight dynamics operations (e.g. plans, procedures, reports, design documentation, software code, problem reporting data, requirements, and requirements documentation and traceability, test plans, test data, analysis, schedules, etc.). The contractor shall conduct all software maintenance and development activities in compliance NPR 7150.2A. The contractor shall provide quality assurance for all operational products.

### **1.1 Operations Support**

#### **1.1.1 Orbit Determination and Analysis**

The contractor shall provide for orbit determination support during launch and early orbit periods and as a routine operation to maintain current orbit definitions. This support includes pre-launch error analysis, pre-launch testing, mission support planning and ground and onboard orbit determination and ephemeris generation. Contract personnel may be required to have US government security clearances.

**1.1.1.1** The contractor shall perform orbit determination and related computation activities in support of scientific and applications spacecraft missions. These activities include routine and periodic special orbit determination support and analysis for selected spacecraft. The routine work is done on a regularly scheduled basis. The special support is done on a scheduled and emergency basis depending on the particular spacecraft.

**1.1.1.2** The contractor shall perform analysis related to spacecraft local oscillator frequency. This analysis includes determining local oscillator frequency history and reporting results to users.

**1.1.1.3** The contractor shall support onboard orbit computations as required. This support may include independent verification of onboard navigation solutions and preparing orbit products for uplink to the spacecraft.

**1.1.1.4** The contractor shall perform critical orbit determination computations for payloads during early operations periods and computations after orbit adjust maneuvers, as required.

**1.1.1.5** The contractor shall perform pre-launch error analysis for upcoming missions for determining amount of tracking data needed, duration of passes, and

## ATTACHMENT A

number of tracking stations needed to satisfy the mission orbit determination requirements.

### **1.1.2 Tracking Data Evaluation and Calibration**

The contractor shall provide support for the validation of radiometric tracking data and tracker calibration assistance. Contract personnel may be required to have US government security clearances.

**1.1.2.1** The contractor shall provide data validation and calibration support of tracking systems to maintain accurate tracker and network performance values. The contractor shall assess the accuracy and usability of the data for the orbit determination process. The contractor shall conduct noise analysis of the radiometric observations and identify erroneous observations. The contractor shall provide information to the appropriate network concerning a deviation in tracker performance from the predetermined norm.

**1.1.2.2** The contractor shall provide calibration support for modified and/or new tracking systems. This support shall include validation of tracking data and verification of tracking system capability. The contractor shall perform analyses to verify data receipt and correct format for new or modified tracking systems.

### **1.1.3 Acquisition Data**

The contractor shall provide support for the generation of acquisition data based on mission requirements. Contract personnel may be required to have US government security clearances.

**1.1.3.1** The contractor shall provide for the generation and transmission of pre-mission and real-time support acquisition data, including on-orbit data for various networks.

**1.1.3.2** The contractor shall provide for the generation of network pre-mission and real-time network scheduling support data.

**1.1.3.3** The contractor shall provide for data quality verification on all acquisition data products generated.

### **1.1.4 Mission Planning and Scheduling Products**

The contractor shall provide for the support, generation and quality assurance of mission planning data products, scheduling products, and related spacecraft products based on individual flight project mission requirements.

## ATTACHMENT A

### **1.1.5 Maneuver Planning Support**

The contractor shall provide planning support and recommendations for orbit maneuver operations. This support shall include orbit adjust computations for flight projects pre-launch and in-flight), operational support for ongoing projects involving orbit adjust maneuvers, performing studies to determine the optimum mission profile that satisfies mission objectives considering all spacecraft or other constraints (e.g. ground station visibility and spacecraft performance capabilities, health and safety, etc.), providing in-flight adaptive mission analysis studies, and providing maneuver planning and execution support as requested for collision avoidance maneuvers for in-flight missions.

### **1.1.6 Human Space Flight Support**

The contractor shall provide for support of manned flight activities. This support includes pre-launch generation and transmission of acquisition data, processing of launch trajectory data, tracking data evaluation, and post-launch generation and transmission of acquisition data. Contract personnel may be required to have US government security clearances.

**1.1.6.1** The contractor shall provide ongoing support for the International Space Station (ISS). This support includes generation and transmission of acquisition data and routine orbit determination.

**1.1.6.2** The contractor shall provide analysis and operations support for vehicles visiting the ISS. This support includes generation and transmission of acquisition data and routine orbit determination, as well as support for proximity operations.

**1.1.6.3** The contractor shall provide analysis and operations planning for future human space flight missions.

### **1.1.7 Expendable Launch Vehicle (ELV) Support**

The contractor shall provide support for expendable launch vehicles. This support includes generation and transmission of pre-launch acquisition data, processing of launch trajectory data, and generation and transmission of post-launch acquisition data updates. Contract personnel may be required to have US government security clearances.

### **1.1.8 USSTRATCOM Liaison**

The contractor shall provide support for NASA missions requiring services from the United States Strategic Command (USSTRATCOM). This liaison will serve as the single point-of-contact to USSTRATCOM, the Air Force Space Command (AFSpC) and the Joint Space Operations Center (JSpOC) to request support services. Support may include: Coordinating data exchange and relevant communication between NASA customers and the Department of Defense (DoD), assisting in processing data requests and in the distribution of approved data products, providing required operational information to any of the DoD entities in accordance with DoD regulations, and providing analysis of requests as approved and directed by the DoD. Contract personnel may be required to have US government security clearances.

## ATTACHMENT A

### **1.1.8.1 Goddard Communications Center Operations**

The Contractor shall operate and maintain the Goddard Communications Center (GCC) during normal day-shift hours; monitor and verify operational health of GCC systems and implement corrective action as required; perform mandatory monthly Communications Security and Cryptologic (COMSEC/Crypto) updates; perform daily check of message logs, and maintain and document total messages processed; support listserv operations and other customer requests; coordinate with USSTRATCOM entities and other line carriers to restore outages of the Automatic Digital Network (AUTODIN) circuit; monitor mail processes, troubleshoot transmission failures, and implement corrective action; perform routine backups of GCC systems as needed; perform configuration management of GCC systems and associated equipment; and, maintain the GCC systems under the GSFC Code 595 Information Technology Security Plan.

## **1.2 Flight Dynamics Systems Engineering**

The contractor shall support integration and maintenance of flight dynamics systems for mission support and update, test and maintain systems in the Flight Dynamics Facility or Mission Operations Control Center (MOCC) environment. System engineering support includes the following.

### **1.2.1 FDF System Engineering**

The contractor shall support the software and hardware maintenance and engineering within the FDF. This support includes, but is not limited to: integration into operations of software and hardware systems, software and hardware maintenance, and user support.

#### **1.2.1.1 Commercial-Off-The-Shelf (COTS) Evaluation and Integration**

The contractor shall support the evaluation of COTS flight dynamics software for use in mission analysis and operations. This support includes development of evaluation criteria, evaluation and reporting of results, and integration of COTS software for mission analysis and operations.

#### **1.2.1.2 Software Maintenance**

The contractor shall provide for the maintenance of flight dynamics software used for technology, analysis, and mission support. This maintenance includes the modification of in-house software and updating to new versions of off-the-shelf software. Flight dynamics tools consist of a combination of in-house developed systems, commercially available products, and extensions to commercially available products developed and/or procured in support of flight dynamics engineers.

#### **1.2.1.3 Configuration Management**

## ATTACHMENT A

The contractor shall provide for the configuration management of flight dynamics systems including hardware and software components.

### **1.2.1.4 Backups and Archiving**

The contractor shall provide support for periodic backup and archiving of designated systems and data that is used for flight dynamics operations, analysis and support.

## **1.2.2 System Facilities Sustaining Engineering**

The contractor shall provide system engineering support for computing facilities, equipment and network, and engineering support for system design.

### **1.2.2.1 System Administration and User Support**

The contractor shall provide the system administration support for the computer systems used to support the FDF. This support includes the configuration of new hardware systems, responsibility for user account administration, system monitoring, and user support and troubleshooting.

### **1.2.2.2 IT Security**

The contractor shall support the implementation of required IT security for computing systems, user protections, and system monitoring. The contractor shall provide assistance in the maintenance of computer system security information and documentation.

### **1.2.2.3 Engineering Support**

The contractor shall support the maintenance and upgrade of hardware systems used in the FDF. This support includes coordinating and procuring hardware or part replacement, installing new hardware and troubleshooting hardware problems, maintaining a list of hardware support contracts, and maintaining an inventory of operational hardware and equipment. This support also includes the identification and requirements analysis for hardware upgrades and providing appropriate logistics services.

### **1.2.2.4 System Engineering**

The contractor shall support the modernization activity within the FDF. This includes support for requirements definition, system design and development, and integration and testing for operations.

### **1.2.2.5 Facility Monitoring**

The contractor shall support operations systems monitoring for the FDF computing systems. This support includes, but is not limited to, coordination of facility operations schedule, coordination of facility maintenance schedule, provide data monitoring for incoming data to the facility, monitoring the FDF

## ATTACHMENT A

HVAC systems, and coordinating maintenance with GSFC facility maintenance organizations.

### **1.2.3 Model Maintenance**

The contractor shall provide the maintenance of various databases and customer interfaces used to perform flight dynamics functions and products.

#### **1.2.3.1 Web Page and Customer Interface Maintenance**

The contractor shall maintain web pages or web-based customer interfaces used for the delivery of flight dynamics information and products.

#### **1.2.3.2 Attitude and Orbit Models and Database Maintenance**

The contractor shall provide analysis and enhancement support needed to update and disseminate attitude and orbit models, and databases. Typical activities may include, but are not limited to, the creation and maintenance of comprehensive and custom star catalogs; maintenance and update of solar flux data; geopotential data; timing coefficients data; tracking data; ground station locations; assignment of station IDs; and the development of analysis specifications for, and enhancements to, attitude and orbit modeling software.

#### **1.2.3.3 Oracle Database Support**

The contractor shall provide maintenance and enhancement support for the operational Oracle database.

### **1.2.4 Automation Techniques**

The contractor shall provide support for the automation of flight dynamics processes for flight projects. The contractor shall provide support for the modernization of flight dynamics processes and systems in support of flight projects. This support includes, but is not limited to, design and integration of new software to meet project requirements and integration of that software into operations.

## **1.3 Conjunction Assessment**

The contractor shall provide support to government personnel for conjunction assessment risk analysis (CARA) services for all NASA unmanned assets. This support is done in conjunction with the Robotic Systems Protection Program (RSPP). The RSPP maintains a close relationship with the Department of Defense, and support is provided to the military as requested. ***This element requires the contractor to hold a Top Secret clearance for performing work in government-owned classified facilities.*** No classified work is required to be performed in the contractor facility.

## ATTACHMENT A

### **1.3.1 Conjunction Assessment (CA) Screenings**

CA screening support includes providing daily screenings of both Owner/Operator ephemerides provided by GSFC as well as JSpOC-generated orbit determination solutions against the high accuracy space object catalog to predict close approach events. Work is performed on site at the Joint Space Operations Center at Vandenberg AFB and requires a TS/SCI clearance.

### **1.3.2 Conjunction Assessment Risk Analysis (CARA)**

CARA support includes providing real-time operations to perform risk analysis of daily screening results to determine threats posed to mission customers, ascent/deorbit/disposal/special maneuver operations; ; assisting missions in planning risk mitigation options as requested; and providing pre-launch analysis of predicted collision threats to mission customers. Contract personnel may be required to have US government security clearances.

## **2.0 Flight Dynamics Analysis**

The contractor shall provide flight dynamics services to flight projects from pre-Phase A through Phase D. The contractor shall also provide research and development (R&D) and technology development services as directed by the Government. The contractor shall provide for the maintenance and development of flight dynamics software that is used for technology development and analysis. Flight dynamics analysis and technology development tasks may include topics such as orbit determination, trajectory control, mission design, trajectory optimization, covariance analysis and measurement models. The contractor shall permit Government insight of all flight dynamics analysis, product development, and test and maintenance activities. The contractor shall permit Government personnel electronic access to documentation generated for or related to flight dynamics analysis (e.g. plans, procedures, reports, design documentation, software code, problem reporting data, requirements, and requirements documentation and traceability, test plans, test data, analysis, schedules, etc.). The contractor shall conduct all software maintenance and development activities in compliance with NPR 7150.2A. The contractor shall provide quality assurance for all operational products.

### **2.1 Flight Project Support**

The contractor shall provide flight dynamics services to flight projects from pre-Phase A through Phase D per the direction of the Government. These services shall be provided by individual task orders that are project funded. Each task order may encompass any of the following analysis topics.

#### **2.1.1 Navigation Analysis**

The contractor shall provide analysis and consultation for planning onboard and/or ground based orbit determination support of flight projects. This support includes, but is

## ATTACHMENT A

not limited to: requirements analysis, covariance analysis, feasibility studies and consultation on network support, tracking infrastructure, measurement models, measurement accuracies, and support scenarios.

### **2.1.2 Mission Design**

The contractor shall provide flight dynamics trajectory planning and mission design and consultation for flight projects. This support includes, but is not limited to: 1. Pre-launch planning for nominal, contingency, and end of life; 2. Pre-launch planning in the areas of trajectory design, launch window analysis and trajectory optimization analysis; 3. Deterministic, statistical, and contingency maneuver planning; 4. Launch support planning and testing in all areas as required; 5. Pre-mission end-of-life trajectory planning.

### **2.1.3 Maneuver Planning**

The contractor shall provide pre-mission planning and consultation concerning deterministic, statistical, and contingency orbit maneuvers that accomplish selected mission objectives for flight projects. This support shall include orbit adjust computations for flight projects that take into account propulsion system modeling and mission constraints, analysis to determine how to reconstruct and calibrate executed maneuvers, and the performance of studies to determine the optimum maneuver scenarios that satisfies mission objectives considering all spacecraft or other constraints.

### **2.1.4 Attitude Determination and Control Analysis**

The contractor shall provide ground attitude determination and control analysis and consultation to flight projects. The contractor shall provide ground attitude system development. The ground attitude system development may be a combination of the multi-mission ground Attitude Determination System (ADS) and mission specific code.

### **2.1.5 Ground System Development**

The contractor shall design, develop, integrate and test ground Flight Dynamics Systems (FDS) for project mission control centers. The FDS may include commercial-off-the-shelf (COTS), government-off-the-shelf (GOTS), automation tools and glueware. The FDS may include orbit determination, flight dynamics product generation, flight dynamics scheduling, maneuver planning and calibration, and flight dynamics trending.

## **2.2 Technology**

The contractor shall provide services associated with the development of new algorithms, techniques, operations concepts, and methodologies to improve capabilities, reliability, services, and cost for flight dynamics support. In addition, the contractor shall provide research into new mission types through the development of new or improved orbits, control techniques,

## ATTACHMENT A

optimization strategies, and onboard orbit/attitude computations. The technologies, models, and techniques developed provide immediate results for mission support, thus enhancing GSFC participation in proposals while expanding capabilities. The contractor shall tailor its support to these efforts as directed by the Government.

The contractor shall provide software systems development required for flight dynamics technology support. Development activities include the analysis of requirements, design, implementation, and test of both institutional (multi-mission) and mission unique software. Also included are the development of scripts, ‘glueware’, and other interface software that may be required to utilize commercial-off-the shelf (COTS) software in GSFC flight dynamics computations. Both onboard and ground software development may be required. Software development methodologies may be adaptive to the individual flight project or application, at the direction of NASA.

### **2.2.1 Advanced Navigation Techniques**

The contractor shall provide support for research, analysis, and related engineering services to support advanced navigation technology initiatives.

**2.2.1.1** The contractor shall provide analysis services for assessing the feasibility of state-of-the-art navigation concepts and algorithms, and engineering services for developing, documenting, maintaining and testing simulation and ground/flight software to implement these advanced concepts, validating the concepts with high-fidelity simulations and flight-data analysis, transitioning the concepts to a mission analysis support environment, and infusing the concepts into mission operations. The navigation concepts to be supported will provide navigation for a wide range of missions including single satellites and satellite formations in low-Earth, high-Earth, gravity assist, libration point, non-Earth planetary, and interplanetary orbits. These concepts will use radiometric, optical, and inertial navigation resources (e.g. Global Positioning System (GPS) technology, Doppler, and range data from the TDRSS or ground station communication links, satellite cross-link measurements, and near- and far-field observations of celestial objects) to estimate onboard or on the ground the absolute and relative navigation and attitude states of one or more satellites, as well as other parameters necessary for navigation.

**2.2.1.2** The contractor shall provide engineering services for the development of navigation, orbit prediction and determination, and error analysis software tools. This includes the development of onboard flight software that performs orbit computations. An example is the GPS Enhanced Onboard Navigation System (GEONS) flight software system. Support includes testing and the assistance in integrating software in flight systems.

ATTACHMENT A

**2.2.2 Advanced Mission Design Techniques**

The contractor shall provide services associated with the development of improved orbit design optimization techniques. This effort shall include research into new orbits that enable new science missions. The models and techniques developed provide immediate results for mission support, thus enhancing GSFC participation in proposals while expanding capabilities. Specific areas of support that may be required include, but are not limited to: optimization of orbits to meet science and engineering requirements while minimizing maneuver impacts, development and application of new mathematical methods to ensure optimal design, investigation of unique orbit designs, and the development of new trajectory design algorithms to directly support GSFC missions. The contractor shall provide services associated with the development of trajectory analysis and design, mission planning, and maneuver planning software.

**2.2.3 Advanced Attitude Techniques**

The contractor shall provide investigation of improvements in the methods by which spacecraft attitude sensor/actuator measurements and reference data are efficiently processed to determine attitudes. With a view to improve mission support and at the direction of NASA, the contractor shall develop new algorithms in the areas of attitude determination, attitude dynamics, attitude modeling, and calibration of attitude actuators and attitude sensors (e.g. gyros and magnetometers). The contractor shall provide services associated with the development of attitude determination, calibration and control software, attitude analysis software, including, but not limited to, attitude dynamics simulators and error analysis tools.

**2.2.4 Formation Flying Techniques**

The contractor shall provide research, as directed by NASA, in the design, control and management of multiple spacecraft flying in formation or as part of a constellation. Required services may include the development of control algorithms for flight or ground use, the development of constellation maintenance approaches, collision avoidance and formation safing strategies, and support to formation flying and constellation management test beds.

**2.2.5 Commercial-Off-The-Shelf (COTS) Evaluation**

The contractor shall provide services associated with the evaluation of COTS flight dynamics software for use in mission analysis and operations. This support includes development of evaluation criteria, evaluation and reporting of results, and integration of COTS software for analysis and operations.

**2.2.6 CAVE Advanced Visualization Environment (CAVE)**

The CAVE is an advanced 4-wall 3-D visualization environment. CAVE activities will provide 3-D stereoscopic visualization for a wide range of missions including single satellites and satellite formations in low-Earth, high-Earth, gravity assist, libration point, non-Earth planetary, and interplanetary orbits. The contractor shall provide services including research, analysis, integration, testing, and related engineering implementation activities to support the flight dynamics CAVE and related visualization technology

## ATTACHMENT A

initiatives. The contractor shall provide assessments of state-of-the-art visualization concepts and industry standards as they apply to the current CAVE design. The contractor shall provide software and engineering services across all common operating system platforms as required for developing, maintaining, implementing, and demonstrating simulations. In addition, the contractor shall provide services, including interfaces between the CAVE and external entities, for non-flight dynamics scientific research, and industry and educational projects.

### **2.2.7 Conjunction Assessment Risk Analysis**

The contractor shall provide analysis services for conjunction assessment and avoidance. *This element requires the contractor to hold Top Secret clearances for performing work in government-owned classified facilities.* No classified work is required to be performed in the contractor facility. Services shall include maintaining and enhancing the NASA Robotic Collision Assessment System (CAS) tool suite as necessary.

### **2.2.8 Relative Navigation System Development**

The contractor shall provide services for the development, analysis, implementation, testing and operations of algorithms and flight software for the purposes of relative navigation, rendezvous and capture of satellites in a space-flight ready system. This includes the development of algorithms for advanced machine vision of the target satellite, advanced navigation and guidance techniques to affect far-field and near-field rendezvous to targets in GEO, LEO, and libration points, filtering techniques for the position and attitude of the target satellite, advanced control methods for positional and attitudinal maneuvering of the chaser satellite, and the analysis techniques to validate the efficacy of these algorithms and their implementations. In addition to these direct capabilities to support a relative navigation system, the contractor shall also provide the ability to implement these algorithms in a flight-like avionics platform and assist in the design and development of the software system to execute the advanced algorithms. Additional support analysis for the relative navigation system includes high accuracy synthetic image generation for cameras and LiDARs, development and implementation of analysis tools, dynamical modeling of the satellite system, modeling of robotics systems, and development of navigation covariance analysis for the purpose of relative navigation. Additionally, the contractor shall support hardware-in-the-loop testing of the system with other elements of an autonomous rendezvous and capture mission, namely a robotic system and satellite actuators and sensors.

ATTACHMENT A

### III. Data Item Descriptions

#### Software Management Plan

The Software Development or Management Plan provides insight into, and a tool for monitoring, the processes to be followed for software development, the methods to be used, and the approach to be followed for each activity. The Software Management Plan will be supplemented with project schedules, organization, and resources for each subsequent task order requiring software development or maintenance activities.

The Software Management Plan shall contain:

- a. Project organizational structure showing authority and responsibility of each organizational unit, including external organizations.
- b. The safety criticality and classification of each of the systems and subsystems containing software.
- c. Tailoring compliance matrix for approval by the designated Engineering Technical Authority, if the project has any waivers or deviations to this NPR.
- d. Engineering environment (for development, operation, or maintenance, as applicable), including test environment, library, equipment, facilities, standards, procedures, and tools.
- e. Work breakdown structure of the life-cycle processes and activities, including the software products, software services, non-deliverable items to be performed, budgets, staffing, acquisition approach, physical resources, software size, and schedules associated with the tasks.

*Note: Item e. above is not required for initial submittal. The contractor shall deliver supplemental updates addressing the above information for specific contract Task Orders as required.*

- f. Management of the quality characteristics of the software products or services.
- g. Management of safety, security, privacy, and other critical requirements of the software products or services.
- h. Subcontractor management, including subcontractor selection and involvement between the subcontractor and the acquirer, if any.
- i. Verification and validation.
- j. Acquirer involvement.

ATTACHMENT A

- k. User involvement.
- l. Risk management.
- m. Security policy.
- n. Approval required by such means as regulations, required certifications, proprietary, usage, ownership, warranty, and licensing rights.
- o. Process for scheduling, tracking, and reporting.
- p. Training of personnel, including project unique software training needs.
- q. Software life-cycle model, including description of software integration and hardware/software integration processes, software delivery, and maintenance.
- r. Configuration management.
- s. Software documentation tree.
- t. Software peer review/inspection process of software work products.
- u. Process for early identification of testing requirements that drive software design decisions (e.g., special system level timing requirements/checkpoint restart).
- v. Software metrics.
- w. Content of software documentation to be developed on the project.
- x. Management, development, and testing approach for handling any commercial-off-the-shelf (COTS), government-off-the-shelf (GOTS), modified-off-the-shelf (MOTS), reused, or open source software component(s) that are included within a NASA system or subsystem.

Note: Verification includes:

- a. Identification of selected software verification methods and criteria across the life cycle (e.g., software peer review/inspections procedures, re-review/inspection criteria, testing procedures).
- b. Identification of selected work products to be verified.

ATTACHMENT A

- c. Description of software verification environments that are to be established for the project (e.g., software testing environment, system testing environment, regression testing environment).
- d. Identification of where actual software verification records and analysis of the results will be documented (e.g., test records, software peer review/inspection records) and where software verification corrective action will be documented.

Note: Validation includes:

- a. Identification of selected software validation methods and criteria across the life cycle (e.g., prototyping, user groups, simulation, analysis, acceptance testing, operational demonstrations).
- b. Identification of selected work products to be validated.
- c. Description of software validation environments that are to be established for the project (e.g., simulators for operational environment). Identification of where actual software validation records and analysis of the results will be documented (e.g., user group records, prototyping records, and where software validation corrective action will be documented).

ATTACHMENT A

## **Software Configuration Management Plan**

The Software Configuration Management Plan describes the functions, responsibilities, and authority for the accomplishment and implementation of software configuration management to be performed during the software life cycle. This plan identifies the required coordination of software configuration management activities with other activities of the project.

The Software Configuration Management Plan shall contain:

- a. The project organization(s).
- b. Responsibilities of the software configuration management organization.
- c. References to the software configuration management policies and directives that apply to the project.
- d. All functions and tasks required to manage the configuration of the software, including configuration identification, configuration control, status accounting, and configuration audits and reviews.
- e. Schedule information, which establishes the sequence and coordination for the identified activities and for all events affecting the plan's implementation.
- f. Resource information, which identifies the software tools, techniques, and equipment necessary for the implementation of the activities.
- g. Plan maintenance information, which identifies the activities and responsibilities necessary to ensure continued planning during the life cycle of the project.
- h. Release management and delivery.

ATTACHMENT A

## Software Assurance Plan

Documents the developers' Software Assurance roles and responsibilities and surveillance activities to be performed as outlined in the NASA Software Assurance Standard.

Reference Documents:

- NASA-STD-8739.8, NASA Standard for Software Assurance
- NASA-STD-8719.13, NASA Software Safety Standard
- IEEE Standard 730-2002, Software Quality Assurance Plans

The Software Assurance Plan (SAP) shall address the following:

- a. Purpose
- b. Scope
- c. Reference documents and definitions
- d. Assurance Organization and Management
- e. Assurance Activities by discipline
  - Software Quality (process and product)
  - Software Safety
  - Software Reliability
  - Software Verification and Validation
  - Independent Verification and Validation (if applicable)
- f. Assurance Activities for Complex Programmable Logic Devices  
(See note below)
- g. Assurance tools, techniques, and methodologies
- h. Software Assurance Program Metrics
- i. Problem Reporting and Corrective Action
- j. Assurance records, collection, maintenance, and retention
- k. Training
- l. Risk Management
- m. Requirements Compliance Matrix (NASA-STD-8739.8 Appendix C)
- n. SAP Change procedure and history