ATTACHMENT J-1
STATEMENT OF WORK
For
FLIGHT MECHANICS DESIGN, MODELING, SIMULATION AND ANALYSIS

1.0 Scope

The Contractor shall provide systems engineering support to the Marshall Space Flight Center (MSFC) Engineering Directorate, including, but not limited to, the Flight Mechanics & Analysis Division of the Spacecraft & Vehicle Systems Department. This shall include, but is not limited to, the Control Systems Design & Analysis Branch and the Guidance, Navigation & Mission Analysis Branch.

The Contractor shall provide Guidance, Navigation and Control (GN&C) Modeling, Simulation and Performance Analysis in the following areas for spacecraft and vehicle systems in support of GN&C systems design, development, analysis, test and verification. The support includes vehicle model development, simulation development and performance analysis, requirement definition and analysis, GN&C flight algorithm development, mission analysis including abort determination and triggers, along with day of launch trajectory optimization design, planning and implementation, stage separation and lift-off analysis, Monte Carlo dispersion analysis and associated requirements and design trade studies. It also includes mathematical modeling, system simulation, design and analysis, and verification for other initiatives. The Contractor shall provide expertise and support in Modeling and Simulation (M&S) and GN&C flight algorithm verification, validation, configuration control and accreditation.

The Contractor shall provide strategic and engineering integration services and expertise in the following areas: facilitate systems integration engineering activities and functions; identify and mitigate system risks; and coordinate/support technical reviews.

The Contractor shall participate in various Technical Working Group (TWG) meetings, interface with the System Integration Groups (SIGs), and participate in monthly reviews and / or telecons to collect the required information for supporting these task processes.

2.0 Task Order Management and Reporting

A. Contractor Management

The Contractor shall provide the planning, coordination, technical direction, and surveillance of the activities necessary to assure disciplined performance of work and timely application of resources for the accomplishment of all tasks issued under the order. The Contractor shall be responsible for maintaining communication with each supported organization and alerting the Contracting Specialist immediately of any problems that would prevent meeting established milestones.

B. Data Requirements Descriptions (DRDs)

The Contractor shall report and document this work and fulfill the requirements of associated Data Requirement Descriptions (DRDs) as outlined in Data Procurement Document (DPD) 1229 (Attachment J-2). The Contractor shall determine the data restriction that applies to each data deliverable and mark or transmit the data restriction in accordance with section 2.3.3 of the Data Procurement Document.

1. The Contractor shall prepare and submit a Monthly Status Report in accordance with DRD1229MA-001. Any presentation, reports, analyses or technical memorandum that is developed during the execution shall be pre-coordinated with the Task Order Monitor and final copies provided to the Task Order Monitor.

   The Contractor shall provide NASA with necessary information on project progress to allow the Government to monitor product assurance, identify significant problems, and implement corrective action as applicable based on the Contractor's performance.

   The Contractor shall develop and maintain a Work Breakdown Structure (WBS) defining all task elements contained in this Task Order and in accordance with established GSA rates per hours worked.

2. The Contractor shall prepare and deliver Badged Employee and Remote IT User Listing in accordance with DRD1229MA-002.

3. The Contractor shall prepare and deliver Contractor Employee Clearance Document in accordance with DRD 1229MA-003.

4. The Contractor shall prepare and deliver Position Risk Designation for Non-NASA Employees in accordance with DRD 1229MA-004.

5. The Contractor shall be responsible for information and information technology (IT) security when physical or electronic access to NASA's computer systems, networks, or IT infrastructure is required or when NASA information is stored, generated or exchanged with NASA or on behalf of NASA, regardless of where the information resides. The Contractor shall prepare a Contract Information Technology Security Program Plan (CITSPP) that documents how the Contractor shall be responsible for information and IT security in accordance with DRD1229CD-001.

6. The contractor shall establish and implement an industrial safety, occupational health, and environmental program that (1) prevent employee fatalities, (2) reduce the number of incidents, (3) reduce the severity of employee injuries and illnesses, and (4) protects the environment through the ongoing planning, implementation, integration and management control of these programs in accordance with DRD 1229SA-001. The SHE Plan shall address each of the following MSFC SHE core

program requirements in detail that are applicable to the contracted effort:

a. Management leadership and employee involvement.
b. System and worksite analysis.
c. Hazard prevention and control.
d. Safety, health and environmental training.

7. The contractor shall report mishaps and safety statistics to the MSFC Industrial Safety Office in accordance with DRD 1229SA-002. The contractor shall submit direct to the NASA Incident Reporting Information System (IRIS) or shall use the forms listed in section 15.4 of DRD 1229SA-002 or electronic equivalent to report mishaps and related information required to produce the safety metrics.

3.0 Technical Requirements

The contractor shall be responsible for information and information technology (IT) security when physical or electronic access to NASA's computer systems, networks, or IT infrastructure is required or when NASA information is stored, processed, generated or exchanged with NASA or on behalf of NASA, regardless of where the information resides.

All data files and reports electronically delivered shall comply with Technical Standard 1194.21 of the Rehabilitation Act of 1973, Section 508.

Tasks shall be defined as follows:

3.1 GN&C Design, Modeling, Simulation and Analysis Support

The Contractor shall provide evaluation of existing structural M&S capabilities and develop a strategy for future development. The strategy will include programming standards and validation of models according to ESMD M&S processes. The Contractor shall analyze Ares I abort modes using GN&C model algorithms. Currently available tools shall be used to perform these analyses and the Contractor shall keep the tools current with Ares I configuration changes. The Contractor shall provide vehicle and modeling analysis support to further develop and improve the Marshall Aerospace VEhicle Representation In C (MAVERIC II) Ares I and I-X dynamic models and simulations. The Contractor shall perform modeling and analysis of Ares I and I-X separation events and Monte Carlo simulation of Ares I and I-X ascent flight. Ares I separation M&S shall be performed for candidate scenarios and configurations. The Contractor shall perform these tasks in the MAVERIC II high fidelity simulation.

The Contractor shall provide support for any of the following sub-tasks:

1) Simulation Structural Model Evaluation and Extension: The effort will include flexible structure and control system interaction analysis to define and assess Ares I preliminary flight control designs for baseline and flight test vehicle configurations.

2) Abort Scenarios Modeling, Analysis, and Algorithm Development: The effort will include the development, modeling, implementation, and testing of various CLV failure and abort scenarios, and abort algorithms. The failure and abort scenarios and abort algorithms will be developed and tested in the Ares I MAVERIC II high fidelity simulation. Failure and abort analysis and algorithm development will be performed for the baseline and any alternate vehicle configurations.

3) Controls Systems Design, Simulation and Stability Analysis: The effort will include the continuing development, coding, testing and stability analysis of candidate control methods for the Ares I ascent vehicle. The time domain stability and performance of candidate control laws will be evaluated in the Ares I MAVERIC II high fidelity simulation. Flex body filter designs will be implemented and tested in conjunction with rigid body control laws in the MAVERIC II simulation environment.

4) Monte Carlo Simulation Studies: The effort will include the ongoing Monte Carlo simulation set-up, execution, and analysis of results for the Ares I ascent flight. Monte Carlo simulations will be performed using the Ares I MAVERIC II high fidelity simulation. Monte Carlo simulation studies will also be performed for candidate trajectories and Ares I configurations.

5) Stage Separation Analysis Support: The effort will support Ares I stage separation analyses using both Treetops and MAVERIC simulation tools. The stage separation analyses will primarily focus on the relative motion between the J-2X nozzle and the interstage. The modeling and simulation effort will include the effects of BDM and USM dispersions including motor thrust profiles, misalignments and thrust pointing vectors, as well as BDM plume impingement and SRB tailoff effects. Analyses will include system parametric studies, MAVERIC Monte Carlo dispersion analysis and RSS analysis.

6) Liftoff Analysis Support: The effort will support Ares I liftoff analyses focusing on liftoff drift, tower contact issues, and SRB plume impingement on the pad and the tower. The M&S will include the effects of winds, SRB thrust misalignment, hold down bolt release delays, etc. The Treetops simulation tool will incorporate the Ares I flight control algorithm from MAVERIC, as well as environmental and physical effects modeled through appropriate initial conditions.

7) Trajectory Optimization and Day-of-Launch Analysis Support: This effort will support the development of a version of the MAVERIC II simulation that is capable of optimizing launch vehicle ascent trajectories without the need for a priori POST trajectory design. A secondary option will include a method of performing day-of-

launch (DOL) wind biasing for the Ares I vehicle. MAVERIC II Monte Carlo analyses with and without DOL wind biasing will be performed to determine the merits of DOL wind biasing.

8) Trajectory Reconstruction Support: The effort will support the implementation of a method for reconstructing Ares I and I-X trajectories in a high-fidelity six degree-of-freedom simulation. Flight reconstruction will be used during the early Ares I flights to ascertain vehicle dynamic response and performance, and will be required to inspect any flight anomalies over the lifetime of the Ares I vehicle. Different methods employed for the space shuttle and other launch vehicles will be considered when developing the Ares I reconstruction method. The various simulations utilized for Ares I will also be considered to determine the best simulation environment to perform the reconstruction development and analyses.

9) System Engineering and Integration (SE&I) Support: The Contractor shall directly support the IDA work package manager for fulfilling IDA work package responsibilities including integration, technical implementation, and the on-time delivery of quality products to the VI project office and other customers. Integration responsibilities shall include planning, evaluations, status of technical disciplines, establishing, tracking, coordinating, and addressing technical actions from Project and Engineering. Responsibilities shall also include supporting and/or providing, as needed, status reviews, project monthly reviews, associated metrics and risk identification, mitigation, and tracking responsibilities for IDA. The Contractor shall perform and/or lead trade study and decision analysis efforts, including technical disciplines, and facilitate decision making for a wide range of Ares I technical issues. The Contractor shall evaluate technical quality and status; provide integration of analyses; and design products and documentation in support of vehicle design, development, operational flight tests and flight operations for the Ares program. The Contractor shall provide subject matter expert support to verification and validation activities for models and simulations used for IDA work package. The Contractor shall review technical reports, requirements documents, and engineering memorandums for technical adequacy and content.

10) Modeling and Simulation (M&S) Management Support: The Contractor shall provide expertise in M&S management support services to implement the planned M&S management activities for the GN&C and Performance and Trajectory Analysis tools for the Flight Mechanics Division. The Contractor shall brief management on the implementation of the M&S management activities, M&S resources and asset management, M&S accreditation activities and provide continued improvement processes to support the developers in instituting systematic practice in M&S configuration management, M&S verification and validation and M&S accreditation.

11) Pogo Analysis and Suppressor Design Support: The Contractor shall provide expertise in ascent vehicle pogo stability analysis, pogo prevention planning, suppressor system design and pogo system test planning and evaluation. The

Contractor shall assess Ares I pogo stability analysis models and simulations along with pogo prevention planning and provide insight and guidance to analysis and planning functions. The Contractor shall perform as directed selected independent pogo stability analysis to provide confidence in in-house models and analysis.

12) Statistical Analysis of Ares I GN&C Performance Simulations: The Contractor shall provide expertise in standard statistical analysis of dynamic simulations. Topics of focus are use of statistics for Ares GN&C analysis, understanding of probabilistic requirements and how to implement them, and understanding all aspects of probability and statistics as they apply to Ares GN&C work.

In support of 1-12 above, the required work shall include, but is not limited to:

- Development of high fidelity models of vehicle dynamics, algorithms, bending, mass properties, sensors, actuators, aero, gravity, and natural and induced environments to assess Ares I and I-X guidance, navigation, control, lift-off, stage separation, aborts, and integrated vehicle performance.
- Development of post-flight model reconstruction capability for I-X. Ares I can use I-X data to validate modeling and simulation capability for Ares I. It also supports Ares I by using I-X for early testing of capability.
- Development, documentation, and verification and validation (V&V) support of M&S plans and analysis.
- Perform the designs, analyses, trade studies, documentation and V&V support of the Navigation system architecture, hardware testing, system parameters, algorithms, filters, and mission timelines.
- Conduct statistical and stochastic analysis using navigation and linearized equations to support requirement, error budget, and design development.
- Assessment of GN&C system nominal and dispersed performance using high fidelity 3DOF and 6DOF simulations.
- Perform the designs, analyses, simulations, documentation and V&V support of the open and closed-loop guidance architectures, system parameters, algorithms, filters, mission timelines, and simulation assessments.
- Development of day-of-launch (DOL) trajectory optimizer package to perform DOL guidance updates to optimize vehicle and payload performance. Development of independent capability to verify that Ares I and I-X are good to fly on launch day.
- Develop methodology for abort scenarios, determine abort cases inferred from vehicle dynamics, analyze the dynamics of abort scenarios, and analyze abort algorithm requirements.
- Perform independent V&V of Ares I-X guidance algorithms and analysis.
- Perform the designs, analyses, trade studies, documentation and V&V support of the FCS architecture, system parameters, algorithms, filters, and mission timelines.

- Develop independent FCS simulation and analysis tools, perform IV&V of FCS algorithms, review dispersed parameter sets, and perform nominal and dispersed FCS performance and stability assessments for the Ares I-X vehicle.
- Perform pogo suppression analysis, design, and derived requirements.
- Develop high-fidelity models and investigate the kinematics and dynamics of lift-off and separation events.
- Develop algorithms to implement the logic for abort scenarios inferred from vehicle dynamics.

3.2 Ascent Performance Analysis and Trajectory Design Support – Closed June 2010

The Contractor shall provide the design and analysis of the integrated vehicle trajectory and performance for the Ares I, Ares V, and the flight test vehicles. It includes the design of reference and design trajectories (i.e., ascent, re-entry, aborts, including static moment balancing) for all design reference missions, trajectories, and performance analyses including partial derivatives, parametric effects on payload, and launch window analyses. It also includes developing, verifying, and maintaining 3-DOF and 6-DOF models and simulations of the integrated Ares I, Ares V, and flight test vehicle configurations. The Contractor shall perform these tasks in the MAVERIC II and POST simulations.

3.3 Vehicle Integration (VI) GN&C System Engineering and Integration (SE&I) Support - Closed July 2010

SE&I Support: The Contractor shall directly support the IDA work package manager for fulfilling IDA work package responsibilities including integration, technical implementation, and the on-time delivery of quality products to the VI project office and other customers. Integration responsibilities shall include planning, evaluations, status of technical disciplines, establishing, tracking, coordinating, and addressing technical actions from Project and Engineering. Responsibilities shall also include supporting and/or providing, as needed, status reviews, project monthly reviews, associated metrics and risk identification, mitigation, and tracking responsibilities for IDA. The Contractor shall perform and/or lead trade study and decision analysis efforts, including technical disciplines, and facilitate decision making for a wide range of Ares I technical issues. The Contractor shall evaluate technical quality and status; provide integration of analyses; and design products and documentation in support of vehicle design, development, operational flight tests and flight operations for the Ares program. The Contractor shall provide subject matter expert support to verification and validation activities for models and simulations used for IDA work package. The Contractor shall review technical reports, requirements documents, and engineering memorandums for technical adequacy and content.

3.4 Upper Stage (US) GN&C SE&I Support - Closed February 2010

System Engineering and Integration (SE&I) Support: The Contractor shall directly support integration, technical implementation, and the on-time delivery of quality products to the US project office and other customers. Integration responsibilities shall include planning, evaluations, status of technical disciplines, establishing, tracking, coordinating, and addressing technical actions from Project and Engineering. Responsibilities shall also include supporting and/or providing, as needed, status reviews, project monthly reviews, associated metrics and risk identification, mitigation, and tracking responsibilities for GN&C integration with US. The Contractor shall perform and/or lead trade study and decision analysis efforts, including technical disciplines, and facilitate decision making for a wide range of Ares I technical issues. The Contractor shall evaluate technical quality and status; provide integration of analyses; and design products and documentation in support of vehicle design, development, operational flight tests and flight operations for the Ares program. The Contractor shall provide subject matter expert support to verification and validation activities for models and simulations used for GN&C integration into US. The Contractor shall review technical reports, requirements documents, and engineering memorandums for technical adequacy and content.

3.5 Ares I-X Vehicle Analysis – Closed December 2009

3.6 Ares V ED Study Reentry Footprint Analysis – Closed March 2010

3.7 MSFC GN&C TDT – Closed October 2009

3.8 Independent Verification of First Stage – Closed July 2009

3.9 US TVC Design and Analysis Support – Closed June 2010

3.10 EDO – MAVERIC Support

Define MAVERIC Test Plan and procedures. Develop MAVERIC generic sensor/navigation code. Standardize and redesign the MAVERIC input data format.

3.11 MDGV-VI Abort Assessment – Closed June 2010

3.12 Spacecraft and Launch Vehicle Control System Design and Analysis Support ***(Authorization to proceed with this subtask will be provided by the Contracting Officer in written direction.)***

The Contractor shall provide engineering support in the design, development, definition, and integration of the flight control system including, but not limited to, system and subsystem requirements or specifications in support of launch vehicles, spacecraft, and instruments. Support shall include, but not limited to, control system design and analysis, Thrust Vector Control (TVC) modeling and analysis support, support of coupled frequency and time domain analyses, flight control integration

support, ascent and reentry flight dynamics analysis, computer simulation and code development, mathematical modeling, model and data configuration management including modeling and simulation (M&S) development activities, and support of verification and test activities. Participation in requirement reviews, technical meetings and working groups shall be required in addition to supporting development of presentations and documentation.

3.13 Spacecraft and Launch Vehicle Guidance, Navigation, and Mission Analysis Support

(Authorization to proceed with this subtask will be provided by the Contracting Officer in written direction.)

The Contractor shall provide engineering support including, but not limited to, the design, development and definition of guidance, navigation, and separation systems including system and subsystem requirements or specifications in support of launch vehicles, spacecraft, and instruments. The Contractor shall provide engineering support for mission analysis to include, but not limited to, trajectory design and analysis, performance analysis, dispersion analysis, ascent and reentry flight dynamics analysis, and abort determination and trigger analysis. Support shall include, but is not limited to, guidance and navigation architecture design, algorithm development, and performance analysis, multi-body flight dynamics including flight separation analysis, mathematical modeling, computer simulation and code development, model and data configuration management including modeling and simulation (M&S) development activities, support of verification and test activities. Participation in requirement reviews, technical meetings and working groups shall be required in additional to supporting development of presentations and documentation.

4.0 Travel

The contractor shall travel as requested to accomplish each technical requirement. Any travel must be approved by the Contractor Officer‘s Technical Representative (COTR) or task order technical monitor, prior to travel.

The contractor’s monthly report shall contain travel detail to include travel destination, dates of travel, number of people who traveled, and purpose of the travel.

5.0 Materials

No materials are currently required for this order. However, this may change based on the customer’s requirements as directed by the Contractor Officer‘s Technical Representative (COTR) or task order technical monitor. Any materials being purchased must be approved by the Contracting Officer prior to purchase.

6.0 Reserved

7.0 Personnel Skill Levels

The Contractor shall provide skills at a level to perform the subtasks in this order.

8.0 Technical Milestones and Deliverables

Specified under Section 2.B of the SOW; any additional deliverables for specific subtasks are specified under Section 3.0.