Attachment 1
Statement of Work

Marshall Space Flight Center
Structural Engineering Analysis Support for the Spacecraft & Vehicle Systems Department and the Propulsion Systems Department in the Engineering Directorate

1.0 General Task Scope

The Contractor shall provide specialized engineering support in vehicle loads and structural and dynamics analysis. Specifically, support will be provided to the Dynamics, Loads & Strength Branch of the Spacecraft & Vehicle Systems Department and the Structural and Dynamics Analysis Branch of the Propulsion Systems Department but may be provided to other branches within these departments. The Contractor shall provide support for programs and projects that include, but are not limited to, the Ares Projects Office, Vehicle Integration Office, Upper Stage Office, Upper Stage Engine Office, First Stage (FS) ARES 1 & 1X Office, and the Shuttle Propulsion Office for the National Aeronautics and Space Administration (NASA) at the Marshall Space Flight Center (MSFC). In order to best define and track the work being provided to each department, two sub elements will be defined.

1.1 Subelement 1 – Spacecraft & Vehicle Dynamics, Loads and Strength Analysis Support

The contractor shall provide structural dynamic analysis, loads, modeling, and documentation support including, but not limited to, the generation of the fatigue and fracture spectra associated with each flight event, loads calculations, and other analyses.

The contractor shall provide structural dynamic analysis, loads, modeling, project management and insight/oversight support for Thrust Oscillation (TO) activities including, but not limited to, methodology development, tool improvement, simulating dynamic systems, defining loads, conducting other analyses, and leading project teams, as required.

The contractor shall provide structural dynamic analysis and loads insight/oversight support including, but not limited to, participating in technical meetings, standing committees, discussions; and thoroughly reviewing all results from assigned tasks to verify outputs are complete, correct, integrated with project objectives; and adequately documented. The contractor support shall include, but is not limited to, reviewing proposed design changes and other technical data pertaining to loads and dynamics; reviewing loads and dynamics analyses provided by the prime contractor; and performing independent insight/oversight modeling and analysis using finite element, classical techniques, simulations, and/or other analyses, as required. The contractor shall follow existing processes and procedures; participate in Process Improvement

Teams, and recommend process improvements where appropriate. Findings and recommendations shall be presented in the form of technical reports and formal presentations.

1.2 Subelement 2 – Structural Analysis and Dynamics Support for Propulsion Systems (ER)

The contractor shall provide structural dynamic analysis and testing support to assist in the assessment of proposed methodologies for performing dynamic, loads and strength calculations for propulsion systems including, but not limited to, engines, upperstage Main Propulsion System (MPS), Reaction Control System (RCS), First Stage, and small solids.

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.

The Contractor shall report and document this work and fulfill the requirements of associated Data Requirement Descriptions (DRD's) as outlined in Data Procurement Document (DPD) 1279 (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.

B. Data Requirements Descriptions (DRDs)

B.1 The contractor shall prepare and submit a Monthly Status Report in accordance with DRD 1279MA-001 as provided in Attachment 2. In addition to the required contents specified in the DRD, the following shall be addressed:

B.1.1. Financial Reporting

NASA will provide to the Contractor the applicable Work Breakdown Structure (WBS) charge code(s) for each subtask. (There may be multiple charge codes for each subtask.) The Contractor shall maintain the WBS defining all task elements contained in this Task Order and track and report cost per these WBS charge codes in accordance with established hourly rates specified in this task order.

B.1.2. Technical Reporting Milestones
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.

B.2 The Contractor shall prepare and deliver Quarterly Technical Reports in accordance with DRD 1279MA-002. Reports shall be submitted via email or electronic media.

B.3 The Contractor shall report mishaps and safety statistics to the MSFC Industrial Safety Branch in accordance with DRD 1279SA-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 1279SA-002 or electronic equivalent to report mishaps and related information required to produce the safety metrics.

3.0 Technical Requirements

3.1 Structural Engineering Analysis Support for the Spacecraft & Vehicle Systems (EV) (Subelement 1)

3.1.1 General Loads Development

Methods, models, forcing functions, software tools, and analyses shall be compatible with existing EV31 models and analysis codes as well as meet other requirements specified by EV31. This task requires broad experience in integrated launch vehicle dynamics modeling and analysis, as well as familiarity with STS elements and MSFC requirements/procedures. This includes extensive experience with Shuttle Level II models and forcing functions, knowledge of multidisciplinary loading events, knowledge of structural dynamic characterizations of guidance and control sensor mounting locations, hydrodynamic characterization and fluid-structure coupling for use in loading and control interaction analyses as well as the ability to transfer assessment of these significant phenomena to developing CLV elements and other support analyses. The task order also requires, as a minimum, skill in NASTRAN for dynamics analysis work (including transient analyses), use of Patran pre-/post-processing software (when utilizing on-site computers) or equivalent such as FEMAP, HYDRO, and FORTRAN or Matlab analysis programming tools. Deliverables, as a minimum, shall be in the form of well-documented NASTRAN analysis or model bulk data files, Fortran or Matlab software programs, as well as technical reports, status reports, briefing charts, etc., will be generated as specified by EV31.

3.1.2 Support of Thrust Oscillation

Methods, models, forcing functions, software tools, and analyses shall be compatible with existing EV31 models and analysis codes as well as

meet other requirements specified by EV31. This task requires broad experience in integrated launch vehicle dynamics modeling and analysis, as well as familiarity with STS elements and MSFC requirements/procedures. This includes extensive experience with Shuttle Level II models and Ares 1 integrated vehicle models, knowledge of multidisciplinary loading events, knowledge of in-depth structural dynamics, knowledge of the dynamic characterization of structures, knowledge of fluid-structure coupling, knowledge of vibration absorbers and isolation systems, and knowledge of control interaction analyses. Task includes modeling integrated vehicle systems, characterizing dynamic systems, assessing systems undergoing thrust oscillation and other corresponding loading environments, conducting sensitivity studies, developing and assessing mitigation plans, providing leadership and project management support to assess complex systems and processes and recommend solutions, performing insight/oversight assessments using dynamic simulations and analyses, and formulating vibration criteria and implementing this criteria in design and test. Deliverables, as a minimum, shall be in the form of well-documented NASTRAN analysis or model bulk data files, Fortran or Matlab software programs, as well as technical reports, status reports, briefing charts, etc., will be generated as specified by EV31.

3.1.2.1 Propellant Damping Support

The contractor shall provide support to the Propellant Damping Task by, but not limited to, implementing the propellant damping physics into a Mechanical Analog model that can be used to work with the Ares structural dynamics models to estimate the effectiveness of the propellant damper at mitigating Thrust Oscillation. The integrated math models shall be used to define the design parameters of the Propellant Damping Device. The contractor shall also provide math models of the different test setups for verifying the mechanical analogs that are developed.

3.1.3 Insight/Oversight of Ares I & I-X Loads for First Stage (FS) Project

This subelement provides EV31 engineering insight/oversight in the areas of loads and dynamics to the Ares 1 and 1X First Stage (FS) Project. The major tasks shall include, but are not limited to:

1) Attending and supporting FS engineering meetings, reviews, and boards, for EV31.
2) Keep EV31 informed of FS work and issues related to structural dynamics and loads.
3) Review/assess FS structural dynamics and loads analyses, methodology, documentation, design and design changes and provide approval or disapproval recommendations.
4) If required, perform independent assessment for EV31 to support insight of FS methodologies, analyses and results.

5) Participate in Ares I Loads and Structures Panel meetings for insight of integrated stack vehicle topics and discussions that affect FS.
6) Participate in Ares I Loads and Structures Panel meetings to support Five Segment Booster (FSB) structural dynamics and loads work and issues topics.
7) Participate in Upper Stage (US) and Mobile Launcher (ML) interface meetings and activities which involve FS interface structural dynamics and loads work and issues.

Methods, models, forcing functions, software tools, and analyses shall be compatible with existing EV31 models and analysis codes as well as meet other requirements specified by EV31.

3.1.4 Shuttle Program Support Scope

This subelement provides structural dynamic analysis and modeling support to EV31 for projects related to the Shuttle. The contractor shall perform modeling, loads calculations and other analyses as required to support EV31. This subelement task requires broad experience in dynamics modeling and analysis, as well as familiarity with STS elements and MSFC requirements/procedures. This includes extensive experience with Shuttle Level II models, knowledge of multidisciplinary loading events, knowledge of structural dynamic characterizations of guidance and control sensor mounting locations; hydrodynamic characterization and fluid-structure coupling for use in loading and control interaction analyses; as well as knowledge of known significant phenomenon associated with the specific STS elements and other support analyses. The subelement also requires, as a minimum, skill in NASTRAN for the dynamics analysis work (including transient analyses) and use of Patran pre-/post-processing software (when utilizing on-site computers). The contractor shall generate deliverables, in the form of Patran databases, NASTRAN bulk data files, status reports, briefing charts, etc. as required. The contractor shall participate in reviews and Technical Interchange Meetings, as required. The contractor shall support monthly activity, quarterly and year-end reports.

3.2 Structural Engineering Analysis Support for Propulsion Systems (ER) (Subelement 2)

3.2.1 Basic Dynamic and Stress Support

Proposed methodologies for the calculation of system dynamic loads and stress analysis associated with the Ares 1 and J-2X engine, upperstage MPS, RCS, First Stage and small solids will be assessed through a combination of hardware testing and analytical modeling. This task will support the creation and use of a structural testbed using the fastrac engine. This support shall include the following tasks:

1) Pre-test consultation and analysis to determine test objectives, required inputs, placement of strain gages and accelerometers, etc.
2) Support during testing to answer questions and address any issues that may arise.

3) Post-test analysis using fastrac mathematical models to compare and assess how well different methodologies are able to predict test results.
4) Test methodologies by also conducting dynamic analysis of other engine systems, such as the Space Shuttle Main Engine (SSME) based on previous test history data.
5) Support MSFC work with prime contractor to implement loads methods as appropriate.

3.2.2 Basic Dynamic and Stress Support for Spacecraft and Launch Vehicles *(Authorization to proceed with this subtask will be provided by the Contracting Officer in written direction.)*

1) The contractor shall provide senior structural analysis support for liquid propulsion system hardware utilized on exploration programs. The engineer shall coordinate the work of more junior analysts and interface directly with propulsion engineering leads for the subsystems being evaluated. Products delivered shall consist of analytical reports and presentations as required by the responsible integrated product team.
2) The contractor shall provide senior turbomachinery structural dynamics analysis support for liquid engine systems utilized on the exploration programs. The engineer shall attend project meetings and develop analytical tools to address dynamics issues as they arise. Products delivered shall consist of analytical reports and presentations, as required, by the responsible integrated product team.

3.3 Spacecraft and Vehicle Dynamics, Loads and Strength Analysis Support for MSFC Center Management and Operations (CM&O) Technical Excellence (Subelement 1)

3.3.1A Hydroelastic Modeling of Fluid Filled Tanks Support *(This* Collected Integrated Loads Analysis System (CILAS) *subtask period of performance is March 15, 2010 through September 30, 2010 and shall not exceed funding level provided to contractor.)*

The contractor shall support hydroelastic modeling of fluid filled tanks tasks including analytically modeling the fluid behavior for the purposes of computing vehicle responses, but not limited to, modernizing HYDRO and BEAMER hydroelastic modeling codes; developing pre- and post-processing graphical tools for integration into a single hydroelastic software package built around the HYDRO and BEAMER codes; developing pre-processing capabilities to visualize and create fluid models for simple shapes including arbitrary axisymmetric tanks; and allow importation of complex 3D fluid meshes created in FEMAP, PATRAN, or some other application. The contractor effort for this task shall also include pre-processor ability to read in a flexible tank structural model to be coupled to the fluid model directly from a NASTRAN bulk data file; modernizing HYDRO and BEAMER codes; modernizing slosh mode eigensolver routines to use algorithms; post-processing capabilities to allow visualization of results using exported results files read into FEMAP or PATRAN to allow visualization of slosh modes, fluid pressures and velocities, fluid mass distributions; automatically generate single DOF

slosh models (spring-mass-damper or pendulum-damper models) used in control system analyses. The contractor shall deliver analysis tools developed under this task no later than September 30, 2010.

3.3.1B Launch Vehicle Ascent Loads Tools Support
(This* Collected Integrated Loads Analysis System (CILAS) *subtask period of performance is March 15, 2010 through September 30, 2010 and shall not exceed funding level provided to contractor.)

The contractor shall support launch vehicle ascent loads tool tasks including, demonstrating and deliver a Monte Carlo based ascent loads tool that more effectively capture statistical enclosure levels of vehicle loads than is currently possible with frozen time snap shot analyses utilized at the current time, but not limited to, (a) synchronization with the trajectory code (e.g., MAVERIC); (b) the utilization of the measured turbulent gust profiles. The simulation tool developed during this task shall be delivered no later than September 30, 2010.

3.4 Spacecraft and Vehicle Dynamics, Loads and Strength Analysis (EV) Support for Shuttle Propulsion Office (Subelement 1)

3.4.1 RSRB Dynamics Loads Support

The contractor shall provide engineering support in structural dynamic analysis and vehicle loads to Reusable Solid Rocket Booster (RSRB) Project Office within the Shuttle Propulsion office.

3.5 Spacecraft and Launch Vehicles Dynamics, Loads and Strength Analysis (Subelement 1) *(Authorization to proceed with this subtask will be provided by the Contracting Officer in written direction.)*

3.5.1 Spacecraft and Vehicle Dynamics, Loads and Strength Analysis

The contractor shall provide structural dynamic analysis, loads, modeling, and documentation support including, but not limited to, the generation of the fatigue and fracture spectra associated with each flight event; modeling, loads calculations, and other analyses; methodology development, tool improvement, simulating dynamic systems, defining loads, conducting other analyses; and leading project teams, as required.

4.0 Travel

The contractor shall travel as requested to accomplish each technical requirement. Travel estimates for the period of performance as listed below. The government will authorize this travel as required during the period of performance.

- Eight (8) trips to NASA JSC in Houston, TX per contract year.
- Eight (8) trips to NASA KSC in Cocoa Beach, FL per contract year.
- Two (2) trips to Canoga Park, CA

The number of trips, travel locations, number of people and length of stay can change based on the customer requirements.

Materials

No materials are required to be furnished or acquired under this order.

5.0 Personnel Skill Levels

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

6.0 Technical Milestones and Deliverables

Models and dynamic analyses shall be delivered as required. The contractor shall provide NASA MSFC access to all models, analyses, results, and inputs files, electronically. Analysis results shall be provided in the form of data files, briefing charts, and reports, electronically. Model deliverables, as a minimum, shall be in the form of well-documented NASTRAN bulk data files, with status reports, briefing charts, etc., as specified electronically. Simulation codes, including inputs and outputs shall be delivered electronically.

Technical memos, data files, briefing charts, and reports and presentations will be provided to NASA MSFC, electronically.

Report deliverables shall be produced using Microsoft Office Products (Word, Excel, PowerPoint, Access and Project).