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NAVAL RESEARCH LABORATORY

Statement of Work for
Aerospace Vehicle Engineering Analysis and Design

4555 Overlook Avenue, S.W.
Washington, D.C. 20375-5000

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List of ACRONYMS

ACA	After Contract Award
ACS	Attitude Control System
AVETS	Aerospace Vehicle Engineering Technical Services
CAP	Contractor Acquired Property
CCN	Configuration Change Notice
CDR	Critical Design Review
CDRL	Contract Data Requirements List
CG	Center of Gravity
COR	Contracting Officer's Representative
EAC	Estimated At Completion
ECN	Engineering Change Notice
ETC	Estimated To Complete
FMEA	Failure Modes and Effects Analyses
GFM	Government Furnished Material
HR	Hazard Reports
ICD	Interface Control Drawings
MAGE	Mechanical Aerospace Ground Equipment
MIS	Management Information System
MOI	Moment of Inertia
MUA	Materials Usage Agreement
MSR	Monthly Status Report
NDI	Non-Destructive Inspection
NDT	Non-Destructive Testing
NMR	Nonconforming Material Report
NRL	Naval Research Laboratory
PDR	Preliminary Design Review
PM	Program Manager
RCS	Reaction Control System
SOW	Statement of Work
TCS	Thermal Control System
TDP	Technical Data Package

1.0 Introduction

This statement of work (SOW) establishes contractor tasks related to the spacecraft research, design, and development responsibilities for the Naval Research Laboratory (NRL) in Washington, DC. This SOW provides for the execution of engineering tasks to support the definition, development, assembly, test, and integration of aerospace platforms, structures, mechanisms, and subassemblies. These aerospace vehicle engineering technical services (AVETS) extend from mission concept and feasibility planning through the Initial Operational Capability (IOC) for Naval aerospace systems, and shall include:
(i) defining systems requirements based on overall mission objectives;
(ii) conducting detailed mechanical, structural, thermal, attitude control and other studies and analyses; (iii) designing, analyzing and testing aerospace structures, mechanisms, and systems to achieve optimal operational systems.

1.1 Mission Background

The NRL is the designated lead laboratory for U.S. Navy space programs. NRL has the mission to preserve and enhance a strong space technology base and to provide expert assistance in the development and acquisition of space systems which support naval missions. Principle NRL functions include: understanding and clarifying mission requirements; conducting research and development activities; analyzing and testing systems to quantify their capabilities; developing operational concepts that exploit new technical capabilities; and developing, testing, and evaluating selected aerospace systems and subsystems.

NRL integrates space systems technologies and provides systems engineering and technical direction assistance for major space systems and other aerospace applications. These roles motivate a continuous search for new technologies and capabilities, and require the development of prototypes that demonstrate the integration of these technologies and capabilities.

1.1.1 Aerospace Engineering Responsibilities

NRL is responsible for designing and building aerospace vehicle platforms in support of Navy missions. NRL provides systems engineering and technical direction while maintaining an active in-house vehicle development, test, and fabrication capability. NRL provides analysis, design, and hardware expertise in structures and mechanisms, attitude control systems, propulsion and reaction control systems, thermal control systems, vehicle design integration, launch vehicle integration, and satellite-to-boost-stage integration. These skills are, also, applied to other aerospace applications. NRL uses both in-house resources and contracts to private industry to achieve its mission goals and objectives.

1.2 Scope of the SOW

This SOW defines the AVETS technical effort required of the Contractor. The work is primarily structural/mechanical in nature. Some of the tasking under the SOW will be required to be performed at the Sensitive Compartmented Information (SCI) level in support of program technical design and development. The attached DD254 provides specific requirements. This effort includes the functions listed below:

- Program Management
- Structural Static and Dynamic Modeling and Analysis
- Vehicle System Loads Analysis
- Structural Response Analysis
- Detailed Stress Analysis
- Fracture Mechanics Analysis
- Structural and Environmental Test Analysis
- Attitude Control System Analysis
- Interface Studies and Technical Reviews
- Structural Design
- Thermal Design and Analysis
- Electro-Mechanical Systems Design
- Optical Systems Analysis
- Research and Development
- Software Development
- Orbit Maneuver Analysis and Flight Operations Support
- Hardware Development
- Robotic Systems Design
- Program Support

2.0 APPLICABLE DOCUMENTS

The following documents, of the issue in effect at the time of contract award, form a part of this SOW only to the extent specified herein. In the event of a conflict between any of the referenced documents and the requirements of this SOW, the contents of this SOW shall be considered a superseding requirement.

2.1 Military Specifications and Standards

Document Number	**Description**
DOD-STD-100	Engineering Drawing Practices
MIL-STD-490	Specification Practices
MIL-T-31000	General Specification For Technical Data Packages

2.2 Program Documents

The Contractor shall comply with the applicable requirements of the following specifications, standards, and publications as they apply to the tasks defined herein.

Document Number	**Description**
SSD-D-004	NRL Drawing Requirements
SSD-D-005	Configuration Management Plan
SSD-D-014	Engineering Data Control and Release Plan

2.3 Non-Government Documents

Document Number	**Description**
ANSI Y14.5M	Dimensioning and Tolerancing

Note: Documents will be available in NRL Bldg. A59. All other documents may be obtained from the Naval Publications and Forms Center, 5801 Tabor Avenue, ATTN: NPODS, Philadelphia, PA 19120-5099. Telephone (215)697-1187/2179.

SSD Documents may be obtained from through the Contracting.

3.0 REQUIREMENTS

The requirements of the SOW are described in this section. The Contractor shall perform the tasks, render the services and deliver complete to specification all services set forth herein.

3.1 General Requirements

3.1.1 Transition Plan

The Contractor shall implement his transition plan within 45 days ACA. Personnel added or replaced after contract award shall be trained within 30 days.

3.1.2 Quick Response

Due to the requirement for quick response and close coordination between NRL and the Contractor, key and resource personnel must be able to respond by telephone and travel between NRL and the Contractor site within 2 hours. The Contractor shall perform work relating to the functions detailed in Section 3.2. On rare occasions it may arise that Contractor personnel must work on short notice to resolve emergent issues such as flight anomalies, flight or test failures, and major unforeseen mission issues. These are by nature short duration events, but may require significant travel and Contractor resources.

3.1.3 Technical Documentation

Technical documentation is defined as drawings, detailed analyses, analytical models, analysis reports, test reports, memoranda, presentation materials and background materials generated by the contractor in performing the work defined in this SOW. The format and style of the documentation generated shall comply with format and style currently being used by NRL. In general, the format and style is consistent with Military Standard and aerospace industry standard practices with minor variations for particular requirements. Documentation generated by the Contractor which is not submitted as a contract data deliverable shall be made available within 14 days of COR request.

3.2 Required Functions

3.2.1 Program Management - Introduction

The Contractor shall provide the leadership and management skills necessary to satisfy the SOW objectives and requirements.

3.2.1.1 Program Control

3.2.1.1.1 Program Manager

The Contractor shall appoint a Program Manager (PM) with overall responsibility for the contracted effort. The PM shall be the point of interface with the Government for all matters concerning technical progress and problems, program performance, schedule, resources, and other program-related activities.

3.2.1.1.2 Project Manager

The Contractor shall assign an on-site Project Manager from the on-site technical staff to oversee the efforts defined herein. The Project Manager shall be responsible for the first-line supervision of all Contractor employees assigned to support the on-site SOW task efforts.

3.2.1.2 Program Status and Reporting

3.2.1.2.1 Management Information System

The Contractor shall implement and maintain a computer-based Management Information System (MIS) of his own design to control and report on the work performed under the individual program tasks. The MIS shall be capable of comparing actual achievement to planned achievement, of comparing accrued costs to planned and budgeted costs, and of providing program control status, progress reporting, and review for each project task effort.

3.2.1.2.2 Monthly Status Report

The Contractor shall prepare and submit a MSR to the COR each month for the duration of the effort. The MSR shall identify any items that will impact, or have impacted, schedule performance, cost, or overall task schedules. The MSR shall provide a status of materials, subcontracts and data items. The MSR shall identify: (i) personnel staffing by name; (ii) manpower usage; (iii) current and cumulative monthly cost data; (IV) accrued costs (including fee); and (v) current and projected funding status. The MSR shall include physical descriptions, estimated and actual prices, and item quantities for all materials and services procured by the Contractor. The Contractor shall provide the MSR in electronic and paper format. The financial aspects of this MSR shall be provided in an ASIC file which can be automatically parsed for direct database entry (alternatively this file may be provided in a mutually agreed to database file format).

3.2.1.3 Program Support Services

3.2.1.3.1 Technical Documentation

The Contractor shall provide writing, editing, drafting, production, and documentation coordination expertise that includes: (i) developing manuscripts for plans and reports; (ii) preparing engineering-level designs and illustrations; (iii) reviewing manuscripts for technical consistency, completion, and specification compliance; (IV) editing and enhancing written text; (v) presenting in-process, preliminary and final manuscripts at document review meetings; and (vi) incorporating "mark ups" and other comments provided by management and technically cognizant personnel. The Contractor personnel involved in this requirement shall communicate directly with managers, scientists, engineers, analysts, and technicians, and shall be familiar with military and NRL documentation specifications. Manuscripts, presentations, and illustrations shall be prepared using software compatible with Microsoft Word, EXCEL and PowerPoint.

3.2.2 Structural Static and Dynamic Modeling and Analysis

The contractor shall perform finite element modeling and analysis tasks to support the design, analysis and test efforts. This function provides finite element models for further analyses in vehicle loads analysis, structural response analysis and analysis results for the detailed stress. All major models will be developed for analysis using the MSC/NASTRAN finite element code. The contractor shall use FEMAP or MSC/PATRAN for pre- and post- processing. Subtasks shall include:

a) Develop, modify and update mathematical structural models of the spacecraft and related structures.

b) Perform static analyses on the structures to determine internal loads, stress levels and other parameters of interest for structural strength analysis.

c) Perform normal modes analyses on the spacecraft structures to determine the modes of vibration and mode shapes, strain energies and other parameters of interest for structural modal analysis.

d) Review the results of the analyses to determine if the results meet the overall program specifications and safety requirements.

e) Develop specialized NASTRAN DMAP routines, where necessary, to accomplish the required analyses.

f) Prepare reports documenting the models and the analyses performed.

g) Provide technical interchange and guidance to NRL personnel in the above tasks

3.2.3 Vehicle System Loads Analysis

The contractor shall prepare models for submission to the launch vehicle contractor for coupled loads analyses on flight systems. Results from these analyses will provide the vehicle system with accurate internal loads for use in the final analysis and design. The launch vehicle systems of interest include the EELV, Minotaur, Taurus, and a variety of other expendable launch vehicles. The analyses will be accomplished using NASTRAN and/or custom developed software that performs large matrix and special mathematical operations . Subtasks shall include:

a) Reduce the vehicle system models to a Craig-Bampton model and mate the reduced system to the launch vehicle interface.

b) Develop the acceleration, loads and displacement transformation matrices for use in recovering the parameters of interest.

c) Prepare the Coupled Loads transmittal documentation. Documentation to have attachments (soft copy) of the Craig Bampton matricies, the Load Transformation Matricies (LTM), and the LTM title files. Documentation shall contain a succinct and accurate description of the delivered math model, names of the specific matricies, number of LTM rows requested, mass properties, cutoff frequency, and a frequency table or any other items as required by the launch vehicle contractor to perform a successful coupled loads run.

d) Perform the required data recovery.

e) Review and analyze the results for accuracy and consistency with program requirements.

f) Develop and/or modify NASTRAN DMAP routines to accomplish the required analysis task.

g) Develop and/or modify custom software to perform the required analysis task.

h) Prepare reports on the analyses performed.

i) Provide technical interchange and guidance to NRL personnel in the above tasks

3.2.4 Structural Response Analysis

The contractor shall perform structural response analyses to satisfy program analysis requirements. These analyses are directed at providing results to support vibration testing and analysis, and model correlation of modal test results. Subtasks shall include:

a) Assemble the vehicle system dynamic models to satisfy the analysis requirements.

b) Develop the appropriate acceleration, loads and displacement inputs for the particular analysis.

c) Perform a transient analysis using the required loads spectrum.

d) Perform the data recovery for accelerations, displacements, loads, stresses and strain energies at select locations in the models.

f) Review and analyze the results to determine if the vehicle system meets the requirements set forth by the program.

g) Correlate math models to data obtained through modal testing.

h) Prepare reports on the analyses performed.

i) Provide technical interchange and guidance to NRL personnel in the above tasks

3.2.5 Detailed Stress Analysis

The contractor shall perform detailed stress analyses on the vehicle system and related structures. These analyses are directed at assuring that the structures meet the program objectives and the strength and safety requirements. Analyses are required to support design development, design changes, design improvements, hardware manufacture and the structural test programs. Subtasks shall include:

a) Review preliminary designs to assure that proper load paths have been developed.

b) Review material selections to assure that the selected materials meet strength requirements and the overall requirements of the program.

c) Perform detailed stress analyses on the components of the spacecraft structures, ground support systems and test hardware to assure that the structures have adequate Margins of Safety to meet program requirements.

d) Review the results of structural static tests to determine if the tests properly loaded the structures being tested. Compare the test results with the analytical results and modify the analyses as required to conform with the tests. Prepare comparison reports to document the reviews.

e) Prepare reports documenting the analysis, analysis methods, and (if used) models. The contractor shall archive all analysis and models in a central program data base.

f) Provide technical interchange and guidance to NRL personnel in the above tasks

3.2.6 Fracture Mechanics Analysis

The contractor shall perform detailed fracture mechanics analyses on spacecraft system structures as required. These analyses will determine the adequacy of the structural parts to meet the program requirements. Analyses will also support proposed design changes, design improvements and hardware manufacture. Subtasks shall include:

a) Prepare written fracture control plans that define the analysis and inspection requirements for NCST programs

b) Perform detailed fracture analyses on spacecraft structural components and systems to determine if the fracture requirements are met. Document the analyses performed.

c) Review and update existing fracture analyses when changes in requirements or loads occur.

d) Prepare and/or revise inspection procedures for special nondestructive testing applications in the fracture mechanics inspection process.

e) Review inspection reports for correctness of procedures and disposition of flawed parts.

3.2.7 Structural and Environmental Test Analysis

The contractor shall perform analysis and test planning to support the static loads, modal survey, vibro-acoustic and other environmental tests for the flight systems and the associated structures.

a) Develop mathematical structural models of the test article.

b) Conduct analyses to determine the loads application requirements, the instrumentation requirements and locations, and test predictions.

c) Review test plans and procedures for conformance to structural analysis requirements and needs.

d) Conduct test functions such as real-time data monitoring to assist in assuring that the test objectives are being met.

e) Review test data results and correlate the results with the analysis results.

f) Review test reports.

g) Prepare reports documenting the analyses performed and the results achieved.

h) Provide technical interchange and guidance to NRL personnel in the above tasks

3.2.8 Attitude Control System Analysis

The contractor shall perform design, analysis, simulation, test and evaluation of complex attitude determination and control systems for spacecraft, launch vehicle and other vehicle systems. The support shall cover the following topics:

a) Configuration analysis
b) Feasibility studies
c) Rigid and flexible spacecraft attitude dynamics
d) Slew, tracking and pointing control strategies
e) Control system/structure interaction theory
f) Experimental digital control techniques
g) Flexible boom deployment dynamics
h) Aerodynamic, geomagnetic and solar disturbance environments
i) Stability analysis
j) Actuator sizing
k) Sensor modeling
l) Damping mechanisms
m) System performance evaluation

This effort shall include support for documenting the design, analysis and other activities and the preparation of reports and presentations when required by the program.

3.2.9 Interface Studies and Technical Reviews

The contractor shall review, evaluate and analyze mechanical design interfaces and the Launch Vehicle/Spacecraft system mechanical interfaces. The contractor shall attend and provide inputs to design reviews of the structural subsystems and components. Documentation resulting from these studies and reviews shall be available per the requirements of Para. 3.1.3.

3.2.10 Structural Design

The contractor shall perform trade studies and detailed structural and mechanical design to support aerospace vehicle development programs, development of ground handling hardware and test hardware.

3.2.11 Thermal Design and Analysis

The contractor shall perform thermal design and analyses to support design development, modifications, improvements and additions. Subtasks shall include:

a) Develop geometrical and analytical thermal models and apply the required environments to satisfy the mission requirements.

b) Perform thermal analyses to determine the TCS design that meets the mission requirements.

c) Review thermal designs, models, analyses and tests to determine the adequacy of the results.

d) Prepare test plans, procedures and perform model correlation for thermal tests.

e) Develop advanced thermal control technology concepts to support advanced mission requirements.

f) Prepare reports for analyses performed and reviews conducted.

3.2.12 Electro-Mechanical Systems Design

The contractor shall perform trade studies and detailed design of electro-mechanical devices and systems for operation in space. Subtasks shall include:

a) Conduct analyses to verify performance and margin.

b) Prepare specifications and development and qualification plans.

c) Review and assess test results and correlate with analysis predictions.

d) Prepare reports on the analyses performed.

3.2.13 Optical Systems Analysis

The contractor shall perform analyses and trade studies in support of Optical/IR systems concepts and implementation. This support shall include component designs, analyses, modeling and test evaluation of optical/IR sensor to determine their adequacy in their planned mission. The contractor shall attend and provide inputs to meetings relating to optical/IR sensors program planning and execution.

3.2.14 Design Studies and Analysis

The contractor shall perform analyses and trade studies in support of flexible structures, thermal control systems and attitude control systems. This support shall include evaluation of designs, modeling, analyses and test evaluation of the systems in order to determine their adequacy in their planned missions. The contractor shall attend and provide inputs to meetings relating to optical/IR sensors program planning and execution.

3.2.15 Software Development

The contractor shall develop and/or modify small software programs to support the activities listed in this Statement of Work. The software shall be developed for the UNIX, DOS or MS Windows operating systems depending on the application requirement. FORTRAN, C++, PERL and MatLab are the preferred languages.

3.2.16 Orbit Maneuver Analysis and Flight Operations Support

The contractor shall perform analysis, simulation, test and evaluation of complex orbit maneuver systems for NRL's spacecraft, launch vehicle and other vehicle systems. The support shall cover the following topics:

a) Advanced concept feasibility studies

b) Orbit maneuver and rendezvous strategies

c) Flight operations support

d) Thruster sizing to support maneuver requirements

3.2.17 Hardware Development

The contractor shall develop hardware for prototype, flight, ground support and test applications. The hardware shall include structural components, mechanisms, electromechanical devices, electronic components, heat pipes, thermal blankets and other devices that support NRL's programs. Subtasks shall include:

a) Fabrication of hardware items per program drawings and specifications.

b) Inspection of hardware items in order to assure that the parts meet the requirements and specifications.

c) Apply protective coatings such as iridite, anodize and paints to protect metal surfaces.

d) Assemble parts per drawing/specification requirements to form higher level assemblies including fully assembled systems.

e) Test parts, assemblies and/or systems to assure that program requirements/specifications are met. Generate test procedures, fabricate support hardware and install instrumentation to support this activity.

f) Create and maintain documentation records that log the manufacturing, inspection and test processes subjected to each part/assembly. Note all anomalies and discrepancies.

3.2.18 System Safety Analyses

The Contractor shall perform analyses and prepare documentation to support payload safety and readiness reviews for expendable launch vehicle launches. Subtasks include:

a) Perform and/or review Failure Modes and Effects Analyses (FMEA's).

b) Develop, evaluate and review Hazard Reports (HR's), Materials Usage Agreements (MUA's), Payload Safety Non-Compliance Reports and Payload Safety Data Packages.

3.2.19 Electrical Engineering

The Contractor shall analyze, design, fabricate, test and integrate electronic systems for the measurement and control of thermal, mechanical and electromechanical systems for ground support and operational applications. Subtasks shall include:

a) Development of Phase Locked Loop motor speed controllers and Pulse Width Modulated proportional temperature controllers.

b) Development of solenoids, motors, eddy current dampers and tachometers.

c) Development of power circuits for drive and commutation of motors.

d) Development of low noise signal conditioning and interface electronics for sensors, optical encoders and thermistors.

e) Development of microprocessor based controllers for performing command and telemetry functions.

f) Development of microprocessor based systems to perform data acquisition, filtering, processing and analysis.

3.2.20 Contamination Control

The Contractor shall perform contamination control planning, analysis, assessment and reporting to support aerospace hardware development. Subtasks shall include:

a) Determine contamination control requirements for sensitive payload hardware.

b) Develop contamination control plans and procedures for protecting sensitive hardware/instruments.

c) Develop analytical transport models and generate contamination hazards predictions.

d) Perform detailed environmental analyses for all activities/events related to the life of sensitive hardware and provide comparison with requirements.