STATEMENT OF WORK
For
AERONAUTICS AND EXPLORATION MISSION MODELING AND SIMULATION (AEMMS)

October 20, 2009

1.0 INTRODUCTION

The principal purpose of this contract is to provide support to research and development activities of the Systems Analysis Branch of the Flight Vehicle Research and Technology Division, the Aeromechanics Division of the Army Aviation & Missile Research, Development & Engineering Center's Aeroflightdynamics Directorate, and the Applied Modeling and Simulation Branch, and the Fundamental Modeling and Simulation Branches of the NASA Advanced Supercomputing (NAS) Division (hereafter known as the Requesting Organizations). This document describes the current and anticipated research programs of the organizations. The major objectives include the development and application of technologies for the design and analysis of aerospace vehicles and systems, large-scale numerical simulations in support of NASA and Army mission critical engineering applications, and fundamental advances in numerical methodologies, algorithms, physical models, and application code development.

2.0 SCOPE OF WORK

2.1 GENERAL SCOPE

The scope of the effort to be performed within this contract is described in this section.

The Contractor shall provide fundamental and engineering research and development, pursuant to contract task orders issued by the Contracting Officer. These services shall include the personnel, facilities, equipment and materials (unless otherwise provided by the Government) to accomplish the tasks.

Task assignments will be issued to perform services in the following areas: project management, systems engineering, systems analysis, research and analysis, design and development, testing, computer modeling, technical writing, computer systems administration, administrative services, and other functions necessary to complete projects. The Contractor shall provide management and administrative functions necessary to effectively and efficiently manage the work performed under this contract.

The Contractor shall perform services to enable the modeling, simulation, and analysis of systems relevant to the NASA aeronautics, exploration, space operations and science missions as required by task order in the following technical areas:

a) Aerospace systems analysis tools development and application
b) Aerospace vehicle and system design, analysis and optimization
c) Computational Fluid Dynamics (CFD) tools development and application
d) High fidelity modeling and simulation of aerospace vehicles and systems
e) Development of improved physical models
f) Integrated multidisciplinary design and analysis framework development
g) Risk analysis methods development and application to aerospace systems
h) Geometry and Grid generation tool development
i) Planetary and Earth Science modeling
j) Modeling and simulation of "green" technology applications
k) Optimization and mission decision support tools and analysis
l) Computational chemistry, computational biology, and computational material science

Specific requirements will be defined for each task order according to the current and future needs of programs and projects involving the requesting organizations. The Contractor may be tasked to accomplish either an entire project from conception to operation, or a specific part of a project such as design or testing.

2.2 CONTRACTOR RESPONSIBILITIES

The Contractor's responsibilities shall include the management of personnel, timely and effective implementation of task assignments, monitoring of any applicable subcontract performance, management of scheduled deliveries, and timely and effective reporting to the Government. These responsibilities shall also include efficient cost and risk management methods as well as procedures to ensure that the Government is aware of task assignment status and progress achieved. Management includes managing financial and personnel resources as well as conforming to established NASA policies and to budgetary guidelines. Most of the work will be performed on-site at Ames Research Center (ARC), Moffett Field, California.

The Contractor shall participate with the Government to upgrade and maintain required plans, procedures, and work instructions in order to maintain the organization's compliance with any third-party quality system and shall participate in any audits to maintain the quality system compliance/certification. Where the Contractor has primary responsibility for a functional or business area, the Contractor shall have primary responsibility for maintaining compliant documentation associated with that area.

The Contractor shall provide qualified management personnel, organizational structure, procedures and administration support functions to effectively and efficiently manage the work performed under this contract. The management and administrative structure shall provide a single point of contact for interface to the Contracting Officer's Technical Representative (COTR) and shall provide procedures and management supervision to ensure compliance with applicable government regulations for accomplishing this contract.

The Contractor shall be responsible for ensuring that all contractor and subcontractor personnel engaged in performance of this Statement of Work have appropriate qualifications, knowledge, and certification to perform work in accordance with the task assignments. The Contractor must have the flexibility to hire personnel at all appropriate levels of skills and experience, including, but not limited to, administrative staff, university students, post-docs, junior and senior research scientists and engineers. The Contractor will support the Requesting Organizations' goals to acquire a highly skilled workforce that is aligned with NASA missions and continues to value intellectual advantage and synergy that is made possible by a diverse workforce. The Contractor will ensure that all foreign national visitors and all employees have completed the required background checks, approvals and clearance requirements for access to the NASA Ames Research Center property.

The Contractor shall provide computer system administration support necessary for the fulfillment of the work of this contract, when tasked by the Government. This work shall include on-site IT support services for desktop, laptop, workstation, and server computers.

Research office and laboratory space, computer hardware, and software, deemed necessary for the direct fulfillment of the task orders will be provided by the Government. The Contractor may purchase, with COTR approval, and in accordance with the Subcontracts clause at FAR 52.244-2, any materials (consumables and non-consumables) necessary for the fulfillment of their task requirements.

The Contractor shall comply with the health and safety requirements contained in APR 1700.1 and the system safety and mission assurance requirements in NPR 7120.5, NASA Space Flight Program and Project Management Requirements, and applicable processes and procedures of the Requesting Organizations.

The Contractor shall comply with software engineering requirements in accordance with:

- NPR 7150.2, NASA Software Engineering Requirements
- APR 7150.2, Ames Software Engineering Requirements

The contractor shall also support educational outreach and internship opportunities from high school to doctorate levels to support NASA programs, to provide students with exposure to public service and enhancement of their educational experience.

3.0 REQUIREMENTS

3.1 GENERAL

3.1.1 Technologies

Research and Development in the Systems Analysis Branch focuses on the development, test, application and evolution of computational modeling and simulation tools and technologies for system and vehicle conceptual analysis and design. In support of the aeronautics and space exploration missions, the branch develops tools and integrated processes to enable new analysis methods in support of technology portfolio, vehicle, and mission analysis. Technologies and tools using high end computing for mission simulation and vehicle design are developed for, and applied to, advanced aerospace vehicle concepts.

The NAS Division develops CFD/IT/Physical modeling and Computational Chemistry technologies to support the Exploration, Aeronautics, Space Operations and Science Missions. Emphasis is on tool development and analysis of mission enabling technologies and engineering applications on NAS High End Computing (HEC) systems. Applications are varied and evolving with the new NASA Exploration and Science missions. Flow regimes range from incompressible through hypersonic velocities. There is a constant need to develop new computational tools to improve the physical model and analysis capability of fluid dynamic and chemical processes. Multiscale modeling in radiation biology and computational material science is another area of current emphasis.

The Aeromechanics Division develops tools for the computational simulation of rotorcraft, including codes to model rotor aerodynamics and methods for the coupling of computational fluid dynamics with computational structural dynamics.

3.1.2 Customers

The Systems Analysis Branch develops and applies technology in support of numerous government and industry customers. Support to the Aeronautics Research Mission is provided to the Hypersonics project to perform system studies on a variety of Access to Space concepts and in the area of entry vehicle and decelerator research and analysis. The Exploration Mission is served through aerodynamic and aerothermodynamic analysis of exploration vehicles including the Orion Crew Exploration Vehicle; performance and risk analysis tool development, integration and test; supporting the design of Thermal Protection Systems for launch and entry vehicles, including Ares V and Orion, and flight risk analysis of launch and entry vehicles, including Ares I and Mars entry vehicles. Cross-cutting support is provided to a variety of Agency studies addressing missions such as Mars entry and sample returns; and to design efforts with Industry and Other Government Agencies for aircraft and space flight vehicles including "green" aircraft technology development and Lighter than Air (LTA) vehicle and mission design and analysis.

The NAS Applied Modeling and Simulation Branch supports the NASA Exploration Systems Mission Directorate (ESMD), Aeronautics Research Mission Directorate (ARMD), and the Space Operations Mission Directorate (SOMD). This involves a wide range of research and application work. Examples mostly include high-fidelity CFD simulations to support qualification for flight and shuttle debris analysis, Ares I and V design analysis and database generation, complex simulations of the shuttle flame trench, and flame propagation within the shuttle vehicle assembly building, rotorcraft simulations, and green technology simulations. Development of new technologies to automate grid generation, solution submission, and data reduction/post-processing is also carried out in support of all three missions. Project work often includes rapid response to complex problems with short time-frames for deliverables.

The NAS Fundamental Modeling and Simulation Branch supports the ESMD, ARMD, SOMD and the Science Mission Directorate (SMD). There is greater emphasis on fundamental research in the areas of rotorcraft, fixed-wing subsonics, supersonics, and hypersonic flight vehicles. Examples include numerical algorithms, new enabling technologies, and physical models to improve the efficiency and accuracy of CFD and computational chemistry simulations for NASA mission applications. These methods are developed for inviscid and viscous flows ranging from incompressible to hypersonic flight conditions. Numerical algorithm development and application codes include Euler, RANS, Detached-Eddy Simulations, Large-Eddy Simulations, and Direct Numerical Simulations.

The Aeromechanics Division is chartered with the development of advanced rotorcraft modeling and simulation capabilities in support of Army aviation.

3.2 SPECIFIC REQUIREMENTS

3.2.1 Integrated Analysis Environments

3.2.1.1 General

This area may include:

- Development of data models, user interfaces and integrated tools and models in support of aircraft, exploration, and planetary entry vehicle design and analysis. Existing and new tools and frameworks will be applied to launch vehicles; entry, descent and landing systems; and atmospheric flight vehicles. The task will include gap analysis to identify requirements for new tools, tool integration, tool modification, and/or tool validation and, with prioritization from government task requestors, further development activities will be driven by this analysis.
- Development, validation, and integration of hypersonic and supersonic decelerator design and analysis tools including integration of fluids and structures codes, and the development of propulsive deceleration analysis capabilities. Support in the identification of analytical gaps and requirements for experimental code validation for decelerators.

- Test and integration of vehicle and system analysis and design environments.
- Development of data specification structures including the development of application-specific data ontologies, data structure development, and the integration of the structure with analysis codes and frameworks.
- Development of multi-fidelity tool integration capabilities, cross-framework integration processes, and process management techniques.
- Development of risk analysis capabilities for exploration vehicles and architectures, launch vehicles, and planetary entry vehicles.

3.2.1.2 Contractor Responsibilities

The Contractor shall be responsible for conducting research and development in the areas described above. Example specific problem areas are given as follows:

a) Support gap analysis to identify requirements for new tools, tool integration, tool modification, and/or tool validation to enable the activities listed in (b).

b) Support in the development, test, and integration of new tools to improve design and analysis of atmospheric flight, launch, and entry vehicles concentrating on the disciplines of aerodynamics, aerothermodynamics, structures and fluid/structures interaction, trajectory, weights and sizing, and TPS sizing.

c) Define and develop integration methods for multi-fidelity processes, including software integration within existing frameworks (e.g., Model Center), and data integration methods.

d) Support in the identification of analytical gaps and requirements for experimental code validation for hypersonic and supersonic decelerator analysis.

e) Support the development of decelerator design and analysis capabilities.

f) Develop and demonstrate methods to integrate engineering level tool processes and frameworks with NAS supercomputers and other cluster environments to enable the integration of high fidelity and parallelized codes within the analysis framework.

g) Develop and validate analysis process management capabilities to enable the selection of appropriate tools and input conditions, given a database of benchmarked tool results across a range of configurations and flight conditions.

h) Develop risk models and risk analysis tools for launch vehicles, exploration vehicles and subsystems, planetary entry vehicles and subsystems (e.g., TPS), and exploration architectures.

3.2.2 Aerospace Vehicle and System Design and Analysis

3.2.2.1 General

This area includes:

• Design and development of vehicle and system concepts for exploration and aeronautics missions.

• Design and development of vehicle and system concepts in support of Industry and Other Government Agency requirements for aircraft, space flight, and planetary entry vehicles.

• Performing technology and system trade studies.

• Development and application of mission performance and risk analysis methods.

• Development and application of mission modeling and simulation capabilities to perform multi-fidelity analysis to predict system performance characteristics and risk profiles.

3.2.2.2 Contractor Responsibilities

The Contractor may be required, by task order, to provide the following support:

a) Perform systems analysis for launch, entry, and descent of exploration and space science missions.

b) Perform systems analysis for atmospheric flight vehicles including the integration of their flight characteristics with the airspace architecture.

c) Develop and apply new methods and processes in support of exploration mission vehicle and system design and analysis. Develop and integrate multi-disciplinary, multi-fidelity analysis models for ascent, abort, earth re-entry, and planetary entry for anticipated vehicle and launch configurations.

d) Perform system and technology trade studies for aeronautics and exploration vehicles and architectures.

e) Develop and validate new engineering and CFD capabilities as required to support the design and analysis of space, atmospheric flight, and planetary entry vehicles.

f) Develop an aerodynamic database of a reference CEV capsule concept, baselined against available Apollo test and flight data. Document best practices for application and set up of CFD codes for different configurations and flight conditions.

g) Develop and apply methodologies for vehicle and systems analysis in support of aeronautics missions.

h) Develop revolutionary concepts for aeronautics in pursuit of NASA goals and objectives for the aeronautics mission. Provide trade studies, and cost and benefits analysis of these concepts. Identify critical revolutionary technologies that will be required to develop these concepts.

i) Develop and apply risk analysis methods to support technology and architecture trades for the exploration mission.

3.2.3 Computer System Administration

3.2.3.1 General

Support branch requirements by providing PC systems administration. Provide regular backups, troubleshoot system problems, perform set-up of new equipment, and update systems as required with all cognizance of and adherence to NASA and NAS IT Security requirements and processes. Oversee use of the Branch model-building machine, identifying requirements for maintenance, new materials, etc.

3.2.3.2 Contractor Responsibilities

The Contractor shall be responsible for developing and supporting technology portfolio analysis and management capabilities. Example specific requirements include:

a) Provide regular backups, troubleshoot system problems, perform set-up of new equipment, and update systems as required.

b) Maintain cognizance of and adherence to NASA IT Security requirements and processes. Communicate regularly to branch management and personnel regarding security requirements and their impacts.

c) Support installation and testing of AUS Linux server and associated compute nodes. Provide installation support for COTS and in-house codes, maintaining configuration control over cluster-installed codes.

3.2.4 NAS Division and Branch Requirements

3.2.4.1 General

Areas of current and future activity include, but are not limited to:

- Computational Fluid Dynamic (CFD) algorithm and tool development
- Space Vehicle Launch and Ascent Analysis
- Space Shuttle Analysis
- Development and application of analysis tools in support of advanced rotorcraft design
- Development of automated CFD parameter-study tools
- Planetary and Earth Science CFD modeling
- Modeling and Simulation of green technology applications
- Computational chemistry modeling

3.2.4.2 Contractor Responsibilities

a) Computational Fluid Dynamic (CFD) algorithm and tool development
    - Advanced finite-difference and finite-volume algorithms
    - Parallel algorithms on NASA high-end computing platforms
    - Overset, unstructured, unstructured prismatic, and Cartesian grid systems
        - ♦ Grid generation and flow-solvers
    - Implicit and explicit methods
    - High-order accuracy
    - Steady and time-accurate flows
    - Turbulence modeling
    - Chemically reacting and multi-phase flows
    - Incompressible, low-speed, transonic, supersonic and hypersonic regimes
    - IT/CFD frameworks and solution environments
        - ♦ Based on UNIX shells, script and computer languages, e.g., C-shell, PERL, PYTHON, MYSQL, XML, F77, F90, C, C++, etc.

b) Space Vehicle Launch and Ascent
    - Vehicle on launch pad with tower
    - Space vehicle ascent trajectory
    - Abort scenario

c) Space Shuttle
    - Return to Flight (RTF)
    - Debris analysis
    - Engine Liquid Propulsion Subsystem
        - ♦ Simulation of entire system
        - ♦ Flow liner crack analysis

d) Simulation of the internal and external environment of green eco-friendly buildings

e) Rotorcraft simulations
    - Improve rotorcraft simulation accuracy and efficiency
        - ♦ Grid adaption, high-order accurate methods, parallel algorithms

- Time-dependent visualization methods
- Multidisciplinary frameworks including CFD, Computational Structural Dynamics (CSD) and rotorcraft trim coupling
- Blade vortex interaction
- Turbulence modeling for rotating rotor blades

f) Automated CFD parameter-study tools
- AeroDB Framework

g) Planetary and Earth Science CFD modeling
- Meso and micro-scale viscous simulations of high-wind events and weather related phenomina

h) Computational chemistry modeling
- Parallel chemistry algorithms on NASA high-end computing platforms
- Accurate theoretical spectroscopy for astronomy, astrobiology, Earth science and entry physics
- Chemical reaction rates and charged particle collision cross sections with applications in space science, astrobiology, Earth science, radiation biology, entry physics, and thermal protection systems
- Multiscale modeling in radiation biology, from Ångstrom scale quantum mechanical description of radiation damage to nucleotides to meso-scale modeling of cell damages
- Multiscale modeling in computational material science, from the atomic level (order of nm) to the macroscopic level (order of mm or cm).

3.2.5 Computational Fluid Dynamics Applications for Rotary-Wing Vehicles

3.2.5.1 General

Computational simulations of rotor aerodynamics typically need to model discrete rotor blades with relative motion between the rotors, the fuselage and surrounding ducts or shrouds. These types of calculations involve multiple overset grids and small time steps to capture the details of the individual rotors.

The Reynolds-averaged Navier-Stokes flow solver that is primarily used for this task is the OVERFLOW-2 code developed by NASA Langley's Pieter Buning. OVERFLOW-2 is a general-purpose Navier-Stokes code designed for fixed wing overset-grid computations on both moving and static grids. For moving-grid simulations, the OVERFLOW-2 code accommodates arbitrary relative motion between vehicle components. The modified code automatically organizes grid components into groups of approximately equal size. This group-wise structure has been exploited to facilitate efficient parallel computations of multi-body problems on scalable computer platforms. On parallel machines, each processor is assigned a group of grids for computation, with inter-group communications performed using the Message Passing Interface (MPI) protocol.

In addition to rotor aerodynamics solutions alone, the Army Aeroflightdynamics Directorate (AFDD) at Ames Research Center is also developing new methods for coupling computational fluid dynamics (CFD) with computational structural dynamics (CSD). The aim is to improve the accuracy for the multi-disciplinary rotorcraft modeling. This CFD/CSD is meant to remedy the fact that methods in that are commonly used by the rotorcraft technical community for coupling rotorcraft elastic and aeroelastic behavior are wholly inadequate to treat the most difficult problems of rotary-wing aeroelastic coupling. Recent applications of AFDD's new CFD and CSD coupling methods have resulted in major advances the ability to accurately model complex rotorcraft aeromechanics problems.

In addition to the coupling of legacy structural dynamics and computational fluid dynamics codes such as RCAS and OVERFLOW, the Army Aeroflightdynamics Directorate is also developing a new software package called Helios, which aims to perform coupled rotorcraft CFD/CSD analysis with improvements in speed, accuracy, and throughput compared with the legacy software tools cited above. The Helios goal is to transform the analysis-test paradigm that currently exists within the domestic rotorcraft industry to one built around high-performance computing

This new Helios software package uses an unstructured-grid CFD code for the near-body flow solver, a uniform Cartesian off-body flow solver, plus a new rotor dynamics and trim model that is truly scaleable. The Army Aeroflightdynamics Directorate needs software developers, software testers, and software quality control experts for this new code development project.

3.2.5.2 Contractor Responsibilities

The Contractor shall be responsible for conducting research in the areas described above. Example specific problem areas are given as follows:

a) Apply coupled versions of the OVERFLOW-2 computational fluid dynamics and the RCAS computational structural dynamics codes to analyze specific Army and NASA rotorcraft problems. These applications will entail structured overset-grid generation for practical rotary-wing fuselages and rotor systems such as the Army's CH-47 Chinook and the UH-60 Blackhawk helicopters.

b) Develop scaleable finite-element computational analysis methods for rotor dynamics and trim. These rotor dynamics and trim models must integrate with the overall Helios CFD/CSD framework for rotor aeromechanics.

c) Take responsibility for software quality control, testing, and evaluation of the new Helios code during its multi-year development cycle.

d) Provide system administration, and support for about 25 PC's that run the Linux operating system. These Linux workstations are used for software development, flow visualization, and analysis of computed rotary-wing flow field solutions. A major part of this requirement will consist of ongoing upgrades to operating system and applications software.

3.2.6 Travel

Contractor personnel may be required to travel for short periods of time to attend meetings, to participate in industry site visits, or to attend technical conferences. The Contractor will budget for these expenses as well as anticipated publication expenses in the submission of the response to a task order or modification to a task order.

3.2.7 CTO Accounting – Move to Deliverables

Since tasks are internally funded by the ARC requesting organization, contractor expense accountability must be accomplished on a task basis.

3.3. PERFORMANCE MEASUREMENT

The Contractor shall adhere to the performance measurements detailed in each task order.

4.0 DELIVERABLES AND REPORTS

Contract deliverables and reports are identified and described in the Data Requirements List attachment to this contract. Task specific deliverables will be defined in each task.

5.0 EMERGENCY PREPAREDNESS AND RESPONSE

The Contractor's obligation may include resolution of unusual or emergency situations. The Contractor may be required to assist NASA, within the general scope of work, but in currently unidentified ways, in preparation for, or in response to emergencies. Obligations under this requirement shall only arise when one or more of the criteria at FAR 18.001, enabling NASA to utilize "Emergency Acquisition Flexibilities", are met. If the emergency preparedness and response requirements result in changes to the contract, all contract adjustments will be processed in accordance with the Changes clause of this contract.

6.0 SYSTEM SAFETY, RELIABILITY, AND QUALITY ASSURANCE

The contractor shall interface and coordinate with the NASA ARC Safety, Environmental and Mission Assurance Directorate for defining and implementing safety, reliability, and quality assurance requirements.

In support of CTOs issued, the Contractor shall comply with, and be an integral part of the Ames Management System. This includes following applicable Ames' procedures that are subject to audit. The Contractor shall attend relevant training, provided by the Government, as required for all on-site employees. Specific procedures will be indicated on each task order response. These procedures include, but are not limited to, the following AMS documents:

NPD 1280.1	NASA Management System Policy
APR 1280.1	Ames Management System (AMS) Quality Manual
NPD 8730.5	NASA Quality Assurance Program Policy

The Ames' Quality System documents can be found at: http://ams.arc.nasa.gov

7.0 PHASE-IN AND PHASE-OUT

Phase-In: The phase-in process shall be accomplished as expeditiously as possible, with a maximum phase-in period of 30 days. The phase-in process shall not adversely impact the work being done by the outgoing contractor. It shall be conducted in a manner consistent with safe operation requirements. The incoming contractor is responsible for providing a qualified contractor staff by the end of the phase-in period.

Phase-Out: Upon completion of this contract, the outgoing contractor is responsible for the orderly transfer of duties and records to the incoming contractor. This should be accomplished in an expeditious manner, consistent with any contract phase-in schedule, while minimally impacting ongoing task orders. The contractor shall submit a phase-out plan no later than 60 days before the end of the contract for Government review and approval.