1.0 Objective

The objective of this proposed task order contract is to develop, demonstrate, and verify advanced propulsion and communications system technologies as part of NASA’s ongoing, long-term aerospace research programs.

2.0 Scope

The Contractor shall furnish all personnel, facilities, equipment, material, supplies, and services, except as may be expressly set forth in the contract agreement as Government Furnished Property, and otherwise do all things necessary to, or incident to, performing and providing the work efforts set forth in the following areas. Contract scope includes analytical and experimental investigations covering a wide variety of propulsion components, sub-components, and technologies having either Government, commercial, or military application. Space hardware deliverables are limited to prototype or experimental hardware. This contract may be used to support all NASA Centers that require work within the scope of this Statement of Work (SOW). The Contractor shall perform task orders in the following technology areas:

2.1 Technology Area 1: Air Breathing Propulsion Technology

Element 2.1.1 Concept Development and Systems Studies
Element 2.1.2 High Power Density Engine Turbomachinery
Element 2.1.3 Advanced Combustors and Alternative Fuels
Element 2.1.4 Low Noise Propulsion Technologies
Element 2.1.5 Inlets and Nozzles
Element 2.1.6 Variable, Combined and Hybrid Engine Systems
Element 2.1.7 Engine Icing
Element 2.1.8 Materials and Structures
Element 2.1.9 Instrumentation, Sensors, Controls and Intelligent Systems

NASA has requirements for the development and demonstration of advanced engine technologies that will enable revolutionary improvements in emissions, noise, capacity, and safety with increased operating efficiency and reduced fuel consumption. These goals will in part be accomplished through the execution of task orders. The technical elements included in Technology Area 1 are as follows:

Element 2.1.1 Concept Development and Systems Studies

The Contractor shall perform concept development and system studies of nontraditional propulsion and/or vehicle arrangements and advanced aerospace systems configurations to meet NASA program goals. These concepts include conventional and unconventional heat engines, electric motors/generators, electric power management and distribution, alternative fuels, alternative energy sources, heat transfer devices, gearboxes, propulsion integration, advanced aerospace systems and advanced operational scenarios such as autonomous vehicles. System studies include performing system analysis and design of aerospace
propulsion systems and their installations on aerospace vehicles to evaluate advanced engine technologies and aerospace system concepts that have the potential for improving system performance, weight, emissions, fuel burn, noise, safety and costs.

The aerospace industry has adopted the NASA developed Numerical Propulsion System Simulation (NPSS) framework as a standard for studying various aspects of the concepts described above. Many of the tasks in this area will require the use of NPSS; therefore, the Contractor must have a demonstrated knowledge of the application of NPSS model development through use in past programs or applications. The demonstrated ability to develop NPSS models for complex unconventional systems as well as integrate new models within the NPSS framework is also required.

The scope of work under this element includes the following:

1. The Contractor shall develop and validate empirical, statistical, and physics-based analytical models that are robust enough to handle non-conventional configurations. These models may be used for understanding the basic underlying physical phenomenon of the system or subsystem as well as for predicting aerospace systems and/or component performance, weight, emissions, reliability, life, safety and cost.

2. The Contractor shall define goals and figures of merit for overall systems as well as for individual technologies within the context of overall program and project goals and objectives.

3. The Contractor shall conduct technology trade studies, mission analyses, safety analysis and market/cost scenario studies to identify and evaluate aerospace systems and assess their contributions towards meeting program and project goals and objectives.

4. The Contractor shall perform system simulations of aerospace systems and subsystems from a 0-D level up through a multi-disciplinary 3-D level.

5. The Contractor shall perform aerospace systems conceptual, preliminary and/or detailed design studies in support of advanced concept definition, development and/or testing.

6. The Contractor shall conduct risk and safety assessments of advanced aerospace systems.

Element 2.1.2 High Power Density Engine Turbomachinery

The Contractor shall identify, evaluate, develop, and demonstrate advanced turbomachinery technologies that result in reduced fuel burn, increased efficiency, increased safety, increased durability, increased operability, reduced noise and/or improved performance of aircraft, rotorcraft, or other aerospace engine systems.

The scope of work under this element includes the following:

1. The Contractor shall develop and provide analysis of conceptual and detailed designs of advanced turbomachinery concepts. These advanced turbomachinery concepts shall contain one or more of the following features:
   a) High-bypass ratio fans and open rotors, advanced low- and high-pressure compressor and turbine components, alternative advanced components, and subsystems
   b) Low-loss variable inlet guide vanes, rotors, stators, transition ducts, seals, and secondary flow systems and struts
c) Efficient wide variable-speed operations
d) Reduction gear systems, lubrication systems, oil-free components, rotor support systems
e) Mitigation of leakages in high-pressure ratio, low corrected flow, and compressor rear stages
f) Aerodynamic stage matching technologies for efficient multistage transonic compressors
g) Advanced turbine cooling concepts and materials
h) Advanced power turbine blades and vanes that are tolerant to large incidences
i) Advanced high-pressure compressor blades that are tolerant to large clearances
j) Advanced casing treatments that allow for efficient operation at low corrected flows
k) Integration of turbomachinery components with hybrid propulsion systems
l) Structural, aerodynamic, aeroacoustic and leakage performance assessment of turbomachinery components and systems as well as their cost and reliability
m) Other features resulting from current system studies

1. The Contractor shall demonstrate advanced turbomachinery technologies in component test rigs including the fabrication and verification testing of advanced fan, compressor and turbine components, seals, reduction gear systems, rotor support systems, secondary flow systems, and subsystems in test rigs.

2. The Contractor shall develop and experimentally validate empirical, statistical, and physics-based analytical models including models as they apply to turbomachinery components and systems for aerospace engines. These include models of turbomachinery, seals, reduction gear systems, rotor support systems, and secondary flow systems.

Element 2.1.3 Advanced Combustors and Alternative Fuels

The Contractor shall identify, evaluate, develop, and demonstrate advanced combustor and fuels technologies that result in reduced emissions, reduced fuel burn, increased efficiency, increased safety, increased durability, and/or improved performance for aerospace engine systems. The Contractor shall also develop analytical design tools as well as identify and evaluate advanced technologies for combustor subcomponents such as fuel injectors, flame-tube and sector combustor test hardware, alternative fuels, combustor liners (metal and ceramic composite), control systems, and ancillary hardware.

The scope of work under this element includes the following:

The Contractor shall develop and validate empirical, statistical, and physics-based analytical models for predicting combustor performance and/or emissions. This includes empirical methods, analogy-based models, and computational combustion chemistry models robust enough to handle non-conventional combustors and fuels and accurate enough that the combustors and engine systems can be designed to a very close tolerance of the actual performance and emissions with very little margin of error. Individual tasks involving the development of new or improved modeling or analysis techniques will identify the accuracy to be achieved and the standard by which that accuracy will be judged. It should be expected that such development efforts will achieve a distinct improvement over the then existing state of the art.

1. The Contractor shall conduct an assessment of advanced concepts, analytical tools, and non-intrusive diagnostics and barrier technologies for the design of combustors.

2. The Contractor shall develop conceptual, preliminary, and/or detailed designs of combustors and their subcomponents such as fuel injectors, combustion liners, fuel supply delivery systems and combustion instability control systems and associated test hardware.

3. The Contractor shall develop and demonstrate ancillary hardware and instrumentation to perform
electronic health monitoring, monitoring of fluid/combustion control functions at real engine operating conditions, emissions and particulate measurements.

a) The Contractor shall demonstrate and validate advanced combustor technologies through fabrication and testing of components and systems. These tests may include flame tubes, sector rigs and full annular combustor rigs, and engine tests with the instrumentation required to assess the aerothermal characteristics, emissions, operability and performance of the combustor concepts.

b) The Contractor shall develop thermal management systems to overcome potential coking problems that include fundamental understanding of jet fuels/alternative fuels and fuel additives under super-heated conditions.

c) The Contractor shall develop, evaluate, and test advanced alternative fuels and fuel additives for aerospace applications.

Element 2.1.4 Low Noise Propulsion Technologies

The Contractor shall develop and demonstrate advanced technologies to reduce aircraft engine noise such as fan noise, jet noise, engine core noise and propulsion/airframe interaction noise. Advanced noise reduction technologies may include those required to enable novel propulsion systems for improved overall performance which may include advanced concepts such as high-speed propellers and novel engine/airframe integration schemes.

The scope of work under this element includes the following:

1. The Contractor shall develop and validate empirical, statistical, and physics-based analytical models for predicting engine and/or engine component noise. This includes empirical methods, acoustic analogy-based models, and computational aeroacoustics techniques robust enough to handle non-conventional geometries (variable cycle, variable duct geometry, etc.), including embedded engines. The models must be accurate enough that the aircraft can be designed to a very close tolerance of the actual noise level with little margin of error. Individual tasks involving the development of new or improved modeling or analysis techniques will identify the accuracy to be achieved and the standard by which that accuracy will be judged. It should be expected that such development efforts will achieve a distinct improvement over the then existing state of the art.

2. The Contractor shall develop conceptual, preliminary, and/or detailed designs of low noise propulsion technologies and low noise propulsion systems.

3. The Contractor shall design and fabricate test hardware for measurement of fan, jet, core, propeller, and engine integration/interaction noise. Additionally, the Contractor shall design and develop diagnostic systems for identifying noise source locations and strength.

4. The Contractor shall demonstrate and assess advanced noise reduction concepts and technologies on component test rigs, engine tests, and flight tests.

Element 2.1.5 Inlets and Nozzles

The Contractor shall identify, evaluate, develop, and demonstrate advanced inlet and nozzle technologies that result in reduced fuel burn, increased efficiency, increased safety, increased durability, reduced noise,
improved performance and/or reduced sonic boom for aerospace engine systems. In addition, the Contractor shall develop and demonstrate advanced technologies that enable high-speed vehicles through use of combined cycle or variable-bypass engine cycles.

The scope of work under this element includes the following:

1. The Contractor shall develop and validate empirical, statistical, and physics-based analytical models for designing and/or predicting performance of inlets and nozzles (e.g., weight, bleed requirements, operability, stability and sonic boom signature). The Contractor shall develop methods robust enough to handle non-conventional geometries (variable cycle, secondary streams, variable duct geometry, embedded configurations, and the like.) and accurate enough that the propulsion system can be designed to a very close tolerance of the actual performance with little margin of error. Individual tasks involving the development of new or improved modeling or analysis techniques will identify the accuracy to be achieved and the standard by which that accuracy will be judged. It should be expected that such development efforts will achieve a distinct improvement over the then existing state of the art.

2. The Contractor shall provide an assessment of advanced concepts, analytical tools and barrier technologies for the design of inlets and nozzles.

3. The Contractor shall provide conceptual, preliminary, and/or detailed designs of advanced inlet and nozzle systems and subsystems.

4. The Contractor shall design and fabricate test hardware for measurement and evaluation of inlet and nozzle performance.

5. The Contractor shall demonstrate and assess performance of advanced inlets and nozzles in wind tunnel, test rigs, and flight tests.

**Element 2.1.6 Variable, Combined and Hybrid Engine Systems**

The Contractor shall develop variable, combined or hybrid cycle engine technologies needed to enable aircraft with enhanced capabilities such as improved performance characteristics over a wider speed range.

The Contractor shall develop advanced engine technologies for supersonic aircraft to change the effective cycle of the engine from high bypass at takeoff to low bypass at supersonic cruise. These technologies may include variable geometry in the fan, compressor, and possibly the turbine. In addition, the Contractor shall investigate and develop engine technologies with more flow streams than traditional turbofan engines to benefit both subsonic and supersonic aircraft by enabling higher operating efficiency at takeoff and cruise conditions.

For even higher Mach number capability necessary for hypersonic engine applications, the Contractor shall investigate and develop technologies to withstand higher temperatures and be capable of even wider operating ranges. These high Mach engines will require additional capability for combined cycle engines to transition from one engine mode (such as a turbine) to alternative propulsion systems such as ramjet-scramjet.

The Contractor shall investigate and develop engine technologies capable of a wide variable speed range for future rotary wing aircraft (i.e., variable speed power turbine assuming fixed speed transmission) to efficiently balance the rotor speed and power requirements between hover and cruise for low fuel burn.
The Contractor shall also investigate and develop hybrid engine technologies such as high power density electric motors, generators, conventional gas turbine components, advanced materials, and associated power management distribution systems and control systems. Hybrid electric propulsion concepts could include alternative power sources/energy storage systems, or turbine engine power sources driving electric motors and propulsors. The Contractor shall develop novel system designs of hybrid electric propulsion systems, components and system analyses of the hybrid electric propulsion system including integration with the airframe, and fabrication and test of associated components and systems.

The scope of work under this element includes the following:

1. The Contractor shall conduct thermodynamic analyses, develop unique flow path layouts, and assess the performance, weight, life, reliability, cost estimation, and control strategies for these advanced engine configurations.

2. The Contractor shall develop conceptual, preliminary and/or detailed designs of the advanced variable and hybrid engine systems.

3. The Contractor shall demonstrate advanced variable and hybrid engine technologies in component test rigs. In addition, the Contractor shall fabricate and conduct system level verification tests of advanced variable engine systems or subsystems.

**Element 2.1.7 Engine Icing**

The Contractor shall perform engine icing research and technology development to address the following challenges: characterization of cloud properties that lead to engine icing, improvements in engine design and simulation tools to prevent ice accretion or mitigate effects of icing, application of engine control methods to protect against engine icing, and technologies to detect hazardous icing conditions.

The scope of work under this element includes the following:

1. The Contractor shall assess advanced concepts, analytical and computational tools and barrier technologies with a focus on understanding and preventing ice accretion, and/or mitigating the effects of engine icing.

2. The Contractor shall develop and validate empirical, statistical, and physics-based analytical and computational models for predicting engine icing and/or its effect on engine performance.

3. The Contractor shall design and fabricate test hardware for the detection and measurement of engine icing. Additionally, the Contractor shall design and develop diagnostic systems for identifying engine icing locations and vulnerabilities.

4. The Contractor shall demonstrate and assess engine ice accretion and performance prediction tools, advanced engine icing prevention and reduction concepts and technologies in component test rigs, engine tests, and flight tests.

5. The Contractor shall identify and characterize weather properties that can lead to engine icing issues

**Element 2.1.8 Materials and Structures**
The Contractor shall develop advanced materials and structures technologies required to meet the aggressive performance and efficiency goals of next generation aerospace propulsion systems. These goals are achievable through increased engine operating temperatures, decreased weight of system components, greater load capabilities, higher safety margins, and innovative fabrication methods such as additive manufacturing. Improvements may be made in physical and mechanical properties as well as in efficiencies in use of materials. The Contractor shall develop such innovative materials, structural concepts, and analytical models using laboratory-, component-, and system-level demonstrations.

The scope of work under this element includes the following:

1. The Contractor shall develop and validate advanced high temperature metal alloys for aerospace propulsion system applications. Alloys are single crystal, directionally solidified, large-grain or fine-grain. This element includes processing and joining methods, disk system concepts and designs, and increased compatibility with advanced coating systems. Advances in metal alloys apply to engine components such as blades, vanes, and disks.

2. The Contractor shall develop and validate advanced ceramic matrix composites (CMCs) for aerospace propulsion system applications. CMCs are developed for increased compatibility with advanced coating systems and include innovative fabrication processes. Advances are made in the mechanics of material modeling as well as modeling of damage and failure modes. CMCs apply to engine components such as combustor liners, turbine blades, vanes, nozzle flaps, seals, and high-speed vehicle leading edge surfaces.

3. The contractor shall develop and validate advanced polymer matrix composites (PMCs) for aerospace propulsion system applications. High temperature PMCs are developed for reduced weight and environmental durability. Lightweight PMC materials and structural concepts are developed for reduced weight and improvement in performance capabilities such as stiffness, strength, impact damage tolerance, durability, and power density. Advanced materials and processing methods such as advanced textile preforms and non-autoclave cure are considered as well as conventional materials and process methods. Advances are made in mechanics of material modeling as well as modeling of damage and failure modes. In addition to propulsion and drive system components, PMCs apply to space structures.

4. The Contractor shall develop and validate advanced environmental barrier coatings (EBCs) for aerospace propulsion system applications. EBCs include advanced thermal barrier coatings for single crystal alloy turbine blades with lower thermal conductivity, increased erosion and impact resistance, and similar or improved oxidation resistance compared to state-of-the-art systems such as yttria-stabilized zirconia coatings. EBCs include advanced coatings for CMC components and include multi-layer coatings for increased durability in extremely harsh environments.

5. The Contractor shall develop and validate advanced metallic, ceramic, polymeric, and other materials including hybrid materials, with tailored properties for aerospace propulsion system applications. Materials include energy storage materials for hybrid electric aircraft technologies, and piezoelectric materials for sensor and actuator applications leading to improved engine efficiency and reduced noise and emissions. Materials are developed with improved structural, thermal, electrical, semiconducting, electrochemical, dielectric, optical, magnetic, and acoustic properties. Material systems include nano-sized structures and composites, solid oxide fuel cell materials, cathode, anode, and electrolyte materials, high temperature SiC semiconductors, piezoceramic materials, and polymer and ceramic aerogels.

6. The Contractor shall develop and validate adaptive structures and materials for aerospace
propulsion system applications. Adaptive tailoring enables transformation of component geometry during specific portions of a mission cycle, or transformation that compensates for changes in component geometry due to degradation during extended engine operation. Adaptive structures include variable area nozzles, active compressor flow control, active compressor blade damping, variable geometry chevrons, and other actuator system concepts and modeling. Adaptive materials include shape memory alloys, polymers, piezoelectric ceramics, and the processing of same, to activate geometry changes with high reliability, weight-savings, and lower complexity compared to heritage electric or hydraulic actuation systems.

7. The Contractor shall develop and validate high-fidelity computationally efficient analytical methods for aerospace propulsion system applications. Analytical methods predict the life of hot engine static and rotating structures fabricated from advanced materials, including metal alloys, ceramic matrix composites, and polymer matrix composites. Analytical methods include multi-scale modeling for advanced materials, and propulsion aeromechanics, among other methods. Analytical methods are validated with strategically selected experiments aimed at single lifing, combined lifing, and multiple-factor combination effects on lifing.

Element 2.1.9 Instrumentation, Sensors, Controls, and Intelligent Systems

The Contractor shall research, analyze, develop and demonstrate advanced instrumentation, sensors, and controls for aerospace applications and autonomous operation at the component and systems level.

The scope of work under this element includes the following:

1. The Contractor shall develop and demonstrate advanced technologies for intelligent systems and subcomponents such as miniaturized smart sensors, actuators and electronics; optical instrumentation; and control algorithms, models and architectures, enabling an engine health management system which includes diagnostics, prognostics, data fusion, and other systems and algorithms capable of assessing and informing the vehicle and other users of the state of a vehicle, propulsion system, sub-system or component as well as providing information to adapt and optimize in response to faults and unanticipated events.

2. The Contractor shall develop active component control technologies such as active compressor control, active combustion control, and active turbine tip clearance control.

3. The Contractor shall develop algorithms, architectures, test beds and demonstration systems to study autonomous, wireless systems at a vehicle and systems level or below (subsystems and components).

4. The Contractor shall conduct research on autonomous vehicles and corresponding emerging technical challenges, including human-machine interactions, certification, verification, validation and trust of autonomous systems, autonomous planning, scheduling and decision-making, test beds and software systems to enhance the test and evaluation of autonomous systems, the design of autonomous systems, and vehicle cooperation and interoperability.

2.2 RESERVED

2.3 RESERVED

2.4 RESERVED
3.0 Work Requirements

The Contractor shall have the ability to perform all work in one or more of the Technology Areas as authorized in each task order issued.

The Contractor shall provide a program management system that includes timely insight into the technical, cost, and schedule status and risk, as well as technical and programmatic control of work performed under the task orders.

The Contractor shall implement a product assurance system, as appropriate, for task orders involving hardware and/or software development. The Contractor’s existing product assurance plans, procedures, formats, and documentation systems that support the development of safe and reliable aerospace products, are acceptable if they are shown to satisfy the objectives of the Product Assurance Requirements listed in the Product Assurance Requirements of NASA Policy Directive NPD 8730.5 NASA Quality Assurance Program Policy—URL:  http://nodis3.gsfc.nasa.gov/displayDir.cfm?t=NPD&c=8730&s=5

All work performed under this contract shall be in compliance with all applicable Federal, state, and local environmental regulations.

Attachment A contains the Task Order Reporting Requirements.

C.2 Government-Industry Data Exchange Program (GIDEP) (June 2013)

(Will only apply to those task orders where it is expressly called out as a requirement).

a. In accordance with NASA Procedural Requirements (NPR) 8735.1, the Contractor shall participate in the Government-Industry Data Exchange Program (GIDEP), and comply with the requirements of the GIDEP Operations Manual (GIDEP S0300-BT-PRO-010) and the GIDEP Requirements Guide (S0300-BU-GYD-010). These documents, as well as other information and materials concerning GIDEP are available from:

GIDEP Operations Center
P.O. Box 8000
Corona, CA 92878-8000

Phone: (951) 898-3207
FAX: (951) 898-3250

Website: http://www.gidep.org
b. The Contractor shall review all GIDEP Notices* and designated NASA Advisories to determine if they affect the Contractor's products and services provided to the Government. The Contractor shall respond by stating, in writing, whether or not each GIDEP Notice and NASA Advisory affects the Contractor's products and services provided to the Government. The Contractor is also responsible for stating whether or not each GIDEP Notice and NASA Advisory affects the subcontractor's products and services provided to the Government. For GIDEP Notices and NASA Advisories that affect the Contractor's products and services provided to the Government, the Contractor shall take action to eliminate or mitigate any negative effect and inform the Government of such actions to ensure GIDEP Notices and NASA Advisories adhere to close-loop reporting**. The contractor shall provide GIDEP Notice and NASA Advisory disposition documentation to NASA up to the time that closed-loop reporting is no longer required. The Contractor shall generate applicable GIDEP Alerts in accordance with the requirements of GIDEP SO300-BT-PRO-010 and SO300-BU-GYD-010 whenever failed or nonconforming items, available to other buyers, are discovered during the course of the Contract.

* The term "GIDEP Notices" means "GIDEP Alerts, GIDEP Safe-Alerts, GIDEP Problem Advisories, and GIDEP Agency Action Notices." Life-cycle logistics should be addressed per contractual requirements identified by the Program/Project.

** The term "close-loop reporting" means providing a written response of no impact, no usage, or impact with rationale at program milestone and readiness reviews or according to contract or other specified reporting times/events for each GIDEP Notice and NASA Advisory.

c. If suspect/counterfeit parts are furnished under this contract, such items shall be impounded by the Glenn Research Center (GRC). The Contractor shall promptly replace such items with items acceptable to the GRC and the Contractor shall be liable for all costs relating to impoundment, removal, and replacement. The GRC may turn such items over to NASA Office of Inspector General, FBI, etc., for investigation, and reserves the right to withhold payment for the suspect/counterfeit items pending the results of the investigation.

d. The contractor is responsible for the flow-down of these requirements to subcontractors and subcontractor adherence to closed-loop reporting. Therefore, the Contractor agrees to insert the preceding paragraphs in any subcontract for supplies exceeding $500,000 and subcontracts of any dollar amount when safety-critical item(s), as identified by the contract, are to be supplied. When inserted, the words, "Contractor" shall be changed to "Subcontractor," and "Government" shall be changed to "Customer."

(End of clause)