Attachment A

STATEMENT OF WORK

RFP NNC06ZDD033R

TURBINE PUMP ASSEMBLY DESIGN & DEVELOPMENT
for the
UPPER STAGE TVC of ARES I

NASA Glenn Research Center

THRUST VECTOR CONTROL TURBINE PUMP ASSEMBLY for ARES I

BACKGROUND

NASA's Space Exploration initiative to return to the Lunar surface and eventually Mars requires new launch vehicles to lift cargo and astronauts to Earth orbit. Ares I will fulfill the manned portion of this task, propelling the Crew Exploration Vehicle (CEV) into Earth orbit. The Ares I will consist of 2-stages: a solid rocket booster lower stage and hydrogen/oxygen liquid upper stage derived from the Shuttle's solid rocket boosters and Saturn's J-2 engines, respectively. The upper stage will utilize a modified J-2 engine that is modified for increased thrust (~294,000 lbf), and incorporates a 2-axis thrust vector control (TVC) system. The schedule for the Ares I include Orbital Flight Test (OFT) beginning in 2012. The contractor shall, in collaboration with the NASA Glenn Research Center, design an Turbine pump Assembly for the Crew Launch Vehicle's Upper Stage Thrust Vector Control system. To meet this aggressive schedule, NASA must initiate development of the upper stage TVC hydraulic system as soon as possible; design and development of a hydraulic turbine pump assembly is the primary purpose of this procurement. Additionally, this procurement will provide for the infrastructure planning required for future fabrication, development testing, verification testing, and delivery of turbine pump assemblies to support the Ares I Upper Stage development and early Ares I flight testing. The procurement for production development, verification, and flight units will be executed under Ares I Upper Stage Production Contractor who will select all subcontractors.

SCOPE

Fulfilling this Statement of Work (SOW) entails a fast-paced effort aimed at reducing the technical and schedule risk by initiating design and development of the turbine pump assembly for the Ares I Upper Stage in time for OFT-1. The turbine pump assembly is defined as a gas driven turbine, a hydraulic pump, a speed control valve, a propellant control valve, and any associated cabling, connectors, etc. The preliminary performance requirements and flight envelope are provided in the Turbine Pump Assembly Performance Specification, Attachment B. In the first task of this effort, the Contractor shall work with NASA and other contractors to complete and deliver an updated Turbine pump Assembly Performance Specification and a Design Specification and shall support NASA in developing applicable Interface Control Documents and Interface Requirements Documents. In the second task, the Contractor shall design and fabricate engineering model hardware for development purposes, test any subcomponent or breadboards deemed necessary by the Contractor, procure engineering model long lead hardware and fabricate, test and deliver four (4) turbine pump assemblies (with an option for 4 additional assemblies) that are flight-like engineering models that have completed an agreed upon test series which proves their capabilities. The Contractor shall also support engineering model testing at GRC. For the third task, the Contractor shall perform preliminary design and analysis for the flight production units, formulate fabrication techniques for production, and present a Preliminary Design Review (PDR) for the flight design. For the fourth task, the Contractor shall complete the detailed design for the flight production units, perform analysis of the TPA including stress, thermal, and vibration, perform final development of fabrication techniques, and present a Critical Design Review (CDR).

The turbine pump assembly consists of the following components, unless otherwise agreed upon:

- Turbine Assembly
- Nozzle and Exhaust Housings
- Propellant Control Valve
- Mechanical Speed Control
- Hydraulic Pump (variable positive displacement with pressure compensation)
- Gearbox/Governor (if required)

Documents that are identified in this Statement of Work, the Turbine Pump Assembly Performance Specification, attachment B, or the Data Procurement Document, attachment C are available from 1) public sites on the World Wide Web, or 2) this site http://exploration.nasa.gov/acquisition/clv.html (see Technical Documents and Presentations).

1 PROJECT MANAGEMENT

The Contractor shall perform management functions and establish a management structure to plan, direct, and integrate all activities required by this Statement of Work (SOW) to assure compliance with technical, schedule, and financial commitments of the contract. The Contractor shall include a process for the timely disposition of corrective actions and provide for the reporting of technical data and financial management data as required. The Contractor shall utilize established management structures and assign a Contractor Project Manager with the authority to direct contract activities. The Contractor Project Manager shall assure that the technical, schedule and cost requirements of this contract are fully met.

1.1 Project Management and Administration

The Contractor shall accomplish the project management and technical control of interdivisional, subcontractor activities required to fulfill the contract requirements. The financial and performance data provided by the Contractor shall provide management visibility into aspects of interdivisional and subcontractor activities relevant to accomplishing the contract requirements. The Contractor shall provide a Work Plan in accordance with The Reports of Work clause in section F of the contract.

1.1.1 Data Management

All data deliverables shall be delivered electronically in common computer formats such as Word, Excel, Acrobat, etc. unless otherwise specified.

The Contractor shall report and document this work and fulfill the requirements of associated Data Requirement Descriptions (DRDs) as outlined in the Data Procurement Document (DPD) CA03C. The Contractor shall determine the data restriction that applies to each data deliverable and mark or transmit the data restriction in accordance with section 2.3.3.2 of the DPD.

1.1.2 Risk Management

The Contractor shall implement a continuous risk management process throughout the life cycle of the contract. The approach shall comply with the Exploration Launch Projects Risk

Management Plan (CxP 72019) and shall comply with the Project's Work Breakdown Structure (WBS). The Contractor shall implement risk management and reporting in accordance with DRD TVC4-MA-CRM. Periodic submittals of DRD TVC4-MA-CRM may be included as part of the Monthly Status Report as described in paragraph 1.2.2.

1.1.3 Project Schedule

The Contractor shall develop, maintain, and track a Project Schedule that is consistent with the Contractor WBS. The Project Schedule shall illustrate the schedule that the Contractor intends to follow over the period of performance. The schedule shall be of sufficient detail to ensure early or late product deliveries and events shall be projected in a timely manner. The Project Schedule shall be expanded if notified by NASA that the level of detail is insufficient. The Contractor shall provide a logic-linked Project Schedule in Microsoft Project 2003, or later, in accordance with DRD TVC4-MA-PS. Changes to the schedule milestones shall require GRC approval. Periodic submittals of DRD TVC4-MA-PS may be included as part of the Monthly Status Report as described in paragraph 1.2.2.

Project Milestones	Approx. Date
Kickoff Meeting	Jan 2007
EM Final Design Review	July 2007
Turbine pump assembly Preliminary Design Review (PDR)	Dec 2007
EM Test Readiness Review (TRR)	May 2008
EM Pre Ship Meeting	July 2008
EM Delivered	Aug 2008
Critical Design Review (CDR)	Dec 2008

Meeting Schedule	Approx. Date
4 TIMs	TB Scheduled

The Contractor may propose to combine two reviews into a single review if it results in moving a review to coincide with an earlier review.

1.2 Business Management

The Contractor shall accomplish the business management control of interdivisional, subcontractor activities required to fulfill the contract requirements. The financial and performance data provided by the Contractor shall provide management visibility into aspects of interdivisional and subcontractor activities relevant to accomplishing the contract requirements.

1.2.1 Financial Management Reports

The Contractor shall provide financial management reports in accordance with The Reports of Work clause in section F of the contract.

1.2.2 Monthly Status Reports

The Contractor shall provide monthly status in accordance with The Reports of Work clause in section F of the contract. The contractor is encouraged to include other monthly data submittals as applicable, which are part of this SOW, as sections within the Monthly Status Report. These data submittals include:

DRD TVC4-MA-PS Program/Project Schedules

DRD TVC4-SA-MSR Mishap and Safety Statistics
DRD TVC4-SE-MPR Mass Properties Report
DRD TVC4-MA-CRM Continuous Risk Management (may be integrated with Section III, Risk Management, in the Monthly Status Report)

If the Contractor chooses to submit periodic DRD's as sections within the Monthly Status Report, they shall be submitted in accordance with the provisions of The Reports of Work clause in section F of the contract rather than the submittal provisions of the individual DRD's in the Data Procurement Document.

1.2.3 Quarterly Status Briefings

The Contractor shall provide quarterly status in briefing format in accordance with The Reports of Work clause in section F of the contract.

1.3 Information Management

The NASA Integrated Collaborative Environment (ICE) is the primary means of sharing, reporting, collecting, recording, and accessing project information between NASA, the Contractor, subcontractors and authorized Government personnel connected with the TVC Project. ICE provides secure, real-time collaborative access to a single source of management information, product information, and technical data. Windchill within ICE is the principal mechanism for integrating a project's digital information management.

a) The Contractor shall use Windchill for delivery of all data requirements documents and contract data deliveries. Windchill shall also be used for review of contract documents and change control activities for class I changes. The Contractor may use its own CM Process for internal configuration management. NASA GRC will set the file structure with the contractor in Windchill and will train the contractor in the use, uploading, viewing and downloading of Contract data.

b) The Windchill file structure will be coordinated with the contractor and made available within 30 days of contract award.

c) The Data Requirements Documents as listed in the Data Procurement Document, Attachment C, shall be delivered to the Windchill TVC Contractor folder.

1.4 Meetings & Reviews

The Contractor shall provide manpower, facilities, and data to support the meetings and reviews defined in this SOW. Other NASA Contractors responsible for vehicle development and NASA direct support Contractors shall have the right to participate in these meetings. All data and information that is delivered or presented at reviews and meetings shall be provided to NASA through the Integrated Collaborative Environment.

The Contractor shall perform all work necessary to close each Review Item Discrepancy (RID). The Contractor shall utilize the RID tool provided by the ICE to manage all RIDs. RID closure requires concurrence from the NASA CO, COTR or ACOTR. No review milestone shall be considered completed until all RID's deemed critical by the NASA COTR are closed.

1.4.1 Bi-Weekly Teleconference

The Contractor shall support a bi-weekly teleconference for, schedule and technical status with the COTR and/or CO at GRC. The Contractor shall include, at a minimum, a review of the program schedule, document status, design and/or fabrication status, problem identification, and efforts undertaken for corrective action.

1.4.2 Kickoff Meeting

The Contractor shall conduct a Kickoff meeting at their facility within 30 days of contract award to present the updated WBS, Schedule baseline and Work Plan.

1.4.3 Technical Interchange Meetings

The Contractor shall support and attend four (4) Technical Interchange Meetings (TIM). The goal is to ensure proper technical and programmatic communication between NASA, the Contractor and other Ares I Contractors. The TIMs will be held at NASA GRC and/or NASA MSFC.

1.4.4 Engineering Model Final Design Review

The Contractor shall present an Engineering Model Final Design Review of an turbine pump assembly, in briefing format, which meets the Turbine pump Assembly Performance Specification. Data required for the review shall be delivered in accordance with DRD TVC4-MA-DRP. This review shall be held at the NASA Glenn Research Center.

1.4.5 Preliminary Design Review

The Contractor shall present a Preliminary Design Review of a production turbine pump assembly, in briefing format, which meets the Turbine pump Assembly Performance Specification. Data required for the review shall be delivered in accordance with DRD TVC4-MA-DRP. This review shall be held at the NASA Glenn Research Center.

1.4.6 Critical Design Review

The Contractor shall present a Critical Design Review of a production turbine pump assembly in briefing format that meets the Turbine pump Assembly Performance Specification. Data required for the review shall be delivered in accordance with DRD TVC4-MA-DRP. This review shall be held at the NASA Glenn Research Center.

1.4.7 Reserved

1.4.8 Reserved

1.4.9 Test Readiness Review

The Contractor shall prepare a Test Readiness Review, in briefing format, per DRD TVC4-MA-TRR, prior to acceptance testing of the EM turbine pump assembly. This review shall be held via teleconference.

1.4.10 Support for NASA-led Reviews

The Contractor shall support the government-led TVC and Ares I Upper Stage System Requirements Reviews (SRRs) and PDRs by providing the appropriate representation at these reviews and supplying additional data as necessary.

2 SAFETY, MISSION & PRODUCT ASSURANCE

2.1 Product Assurance

The Contractor shall implement a Product Assurance Plan (PAP) in accordance with DRD TVC4-RM-PAP. NASA and its assigned S&MA support Contractors shall be provided full access to all engineering, reliability, system safety and quality analysis, records and all engineering documentation, trade studies and various processes, meetings and technical deliberations to part of the decision making process along with the Contractor. The PAP shall document planned implementation compliance with the level III requirements described in the Exploration Launch Projects Safety, Reliability, and Quality Assurance Plan (CxP 72020).

2.2 System Safety

2.2.1 System Safety Plan

The Contractor shall submit and implement a System Safety Plan in accordance with DRD TVC4-SA-SSP.

2.2.2 System Safety/Hazard Analysis

The Contractor shall submit a System Safety/Hazard Analysis in accordance with DRD TVC4-SA-HA and a Fault Tree Analysis per DRD TVC4-SA-FTA.

2.2.3 Support for Upper Stage Hazard Analysis

The Contractor shall support the NASA Upper Stage System Safety Hazard Analysis effort, as requested, by providing technical expertise and input related to the Turbine pump assembly and associated system hazards during all mission phases.

2.3 Industrial, Environmental, Processing Site, and Operations Site

2.3.1 System Safety Plan & Agreement

The Contractor shall submit and implement a Safety, Health, and Environment Plan in accordance with DRD TVC4-SA-SHP, and a Safety, Health, and Environment Work Agreement per DRD TVC4-SA-SHEWA.

2.3.2 Mishap and Safety Report

The Contractor shall submit and implement a Mishap and Safety Statistics Report in accordance with DRD TVC4-SA-MSR. Periodic submittals of DRD TVC4-SA-MSR may be included as part of the Monthly Status Report as described in paragraph 1.2.2.

2.4 Reserved

2.5 Quality Assurance

2.5.1 Quality System

The Contractor shall submit a Quality Plan in accordance with DRD TVC4-QE-QP. The Contractor's quality system shall be compliant to SAE AS9100B and ANSI/ISO/ASQ Q9001-2000. The Contractor can satisfy this requirement by current registration by a

recognized registrar followed up by a verification audit performed by GRC. If NASA has accepted the Contractor's AS9100 registration and Contractor subsequently changes registrars, loses its registration status, or is put on notice of losing its registration status, it shall notify Customer's procuring Component(s) within three days of receiving such notice from its registrar.

2.5.2 Government-Industry Data Exchange Program

The Contractor shall participate in the Government-Industry Data Exchange Program (GIDEP) in accordance with the requirements of the GIDEP S0300- BT-PRO-010 and S0300-BU-GYD-010, available from the GIDEP Operations Center, PO Box 8000, Corona, California 91718-8000. The Contractor shall review all GIDEP ALERTS, GIDEP SAFEALERTS, GIDEP Problem Advisories, GIDEP Agency Action Notices, and NASA Advisories to determine if they affect the Contractors products/services provided to NASA. For those that affect the program, the Contractor shall take action to eliminate or mitigate any negative effect to an acceptable level. The Contractor shall generate the appropriate failure experience data report(s) (GIDEP ALERT, GIDEP S AFE-ALERT, GIDEP Problem Advisory) whenever failed or nonconforming items, available to other buyers, are discovered during the course of the contract.

2.5.3 Materials and Processes Identification and Usage List

The Contractor shall deliver a Materials and Processes Identification and Usage List in accordance with DRD TVC4-MP-MIUL for the Turbine pump assembly designs.

2.5.4 Materials and Processes Selection Plan

The Contractor shall develop and implement a Materials and Processes Selection, Implementation, and Control Plan in accordance with DRD TVC4-MP-MPCP.

2.5.5 Materials Usage Agreement

The Contractor shall deliver a Materials Usage Agreement in accordance with DRD TVC4-MP-MUA.

2.5.6 Contamination Control Plan

The Contractor shall deliver a Contamination Control Plan in accordance with DRD TVC4-MP-CCP.

2.5.7 Nondestructive Evaluation Plan

The Contractor shall deliver a Nondestructive Evaluation Plan in accordance with DRD TVC4-MP-NDE.

2.5.8 Electrical, Electronic, and Electromechanical (EEE) Parts

The Contractor shall utilize flight qualifiable EEE Parts, per MSFC-STD-3012 EEE Parts Management and Control for MSFC Space Flight Hardware, and NPD 8730.2 NASA Parts Policy for both design and fabrication activities. The Contractor shall detail their plans for the management and control of EEE parts for the product being procured in a EEE Parts Control Plan prepared in accordance with DRD TVC4-DE-PCP. The use of nonstandard EEE parts in the design shall require joint Government and Contractor approval through Nonstandard Parts Approval Requests in accordance with DRD TVC4-DE-NPAR. As-designed EEE parts usage shall be documented in an As-Designed EEE Parts List in accordance with DRD TVC4-DE-EEEPL. The traceability records for EEE parts installed in delivered product shall be documented in an As-Built EEE Parts List in accordance with DRD TVC4-DE-EEEPL.

2.6 Reliability, Maintainability, and Supportability

The Contractor shall conduct risk-based design activities for components, elements, and processes of the Turbine pump assembly. This effort will support element and system design activities and will directly feed the overall project risk assessment for the Ares I and the associated management of these risks.

2.6.1 Reserved

2.6.2 Reliability Analysis

The Contractor shall provide a Reliability Allocation, Predictions and Analysis Report in accordance with DRD TVC4-RM-RPAR.

2.6.3 Maintainability Analysis

The Contractor shall provide a Maintainability Allocation, Prediction and Analysis Report in accordance with DRD TVC4-RM-MPAR.

2.6.4 Reserved

2.6.5 Limited Life Item List

The Contractor shall provide a Limited Life Items List in accordance with DRD TVC4-RM-LLIL.

2.6.6 Failure Modes and Effects and Critical Items List

The Contractor shall prepare a Failure Modes and Effects Analysis and Critical Items List (FMEA/CIL) in accordance with DRD TVC4-RM-FMEA. A FMEA will be performed by NASA as part of the Upper Stage design effort with participation of component Contractors through all the phases of the program. The Turbine pump assembly Contractor shall support the Upper Stage FMEA/CIL effort, as requested, by providing technical expertise and input related to the Thrust Vector Control System.

3 SYSTEMS ENGINEERING AND INTEGRATION

3.1 Systems Engineering Management

The systems engineering effort shall include the design and engineering essential to define, evaluate, allocate and specify Contractor derived hardware requirements. The Contractor shall work with NASA in developing the Turbine pump Assembly Performance Specification, DRD TVC4-SE-SPEC, starting from the Turbine pump Assembly Performance Specification in Attachment B. The Performance Specification shall define functional requirements of the Turbine pump Assembly, the environment in which it must operate, interface characteristics and criteria for verifying compliance.

The Contractor shall work with NASA in developing the Turbine pump Assembly Design Specification, DRD TVC4-SE-SPEC. The Design Specification shall specify design requirements such as materials to be used, how a requirement is to be achieved, or how an item is to be fabricated or constructed and how a requirement shall be verified.

3.2 Configuration Management

The Contractor shall establish a configuration management program that addresses all new and/or modified hardware and documentation resulting from this contract. The Contractors CM program shall provide configuration identification, configuration control, configuration status accounting, verification and audit on all hardware and documentation.

3.3 Hardware Configuration Management

The Contractor shall implement a Configuration Management (CM) program that addresses all new and modified hardware, including Government Furnished property for the duration of this contract on hardware, in accordance with the National Consensus Standard for Configuration Management, EIA-649A. The Contractor's CM program shall provide the following: (1) configuration identification, (2) configuration control, (3) configuration status accounting, and (4) configuration management verification and audits.

3.3.1 Configuration Management Plan

The Contractor shall generate and deliver a Configuration Management Plan (CMP) in accordance with DRD TVC4-CM-CMP, which defines the Contractor's CM program and methods for implementation of the contract requirements. The Contractor shall provide the workforce, facilities and materials required to implement the CM program requirements, including the generation, updates and maintenance of all technical documentation.

3.3.2 Configuration Identification

The contractor shall select the Configuration Items (CIs) in cognizance with the government to be identified and assign hierarchical identifiers to each CI, define and document interfaces between CIs, and establish a release system for the control of configuration documentation and computer software code. The hardware configuration shall be identified by the Functional Baseline, Allocated baseline and the Product Baseline.

3.3.3 Functional Baseline

The initial functional baseline for this development effort shall be the Turbine pump Assembly Performance Specification, Attachment B. After contract award and incorporation of agreed upon specification changes and baselining of the Performance, the Contractor shall propose configuration changes or new configurations through Engineering Change Proposals (ECPs) to change the design requirements that describe the designs for the Engineering Model and Flight Turbine pump assembly Assemblies.

3.3.4 Allocated Baseline

The Allocated Baseline for the Engineering Model Turbine pump assembly are the technical specifications, source control documents, drawings, procedures, and any other technical documentation required to identify and verify the Engineering Model product's performance, functional, and physical attributes.

The Allocated Baseline for the Flight Turbine pump assembly are the technical specifications, source control documents, drawings, procedures, and any other technical documentation required to identify and verify the Flight product's performance, functional, and physical attributes.

The Contractor shall control the configuration of Turbine pump assembly Assemblies through internal CM processes. Changes that require text changes to the Turbine pump

Assembly Performance Specification or the Turbine pump Assembly Design Specification shall be submitted as ECPs.

NASA shall have approval authority over all Turbine pump assembly allocated baselines.

3.3.5 Product Baseline

The Turbine pump assembly Engineering Model product baseline shall be that documentation for the Turbine pump assembly configuration that is accepted by NASA and meets the Engineering Model performance requirements of the Turbine pump Assembly Performance Specification.

The Turbine pump assembly Flight product baseline shall be that documentation for the Turbine pump assembly configuration that is accepted by NASA and meets the Flight performance requirements of the Turbine pump Assembly Performance Specification.

NASA shall have approval authority over all Turbine pump assembly product baselines.

3.3.6 Request for Change or Deviation, Waivers, and Accounting

All Contractor requests for changes to the Turbine pump Assembly Performance Specification or the Turbine pump Assembly Design Specification shall be submitted using ECPs as defined in ICE. The substantiating data shall present the impact of the configuration changes required to achieve conformance with Turbine pump Assembly Performance Specification or Design Specification.

Change Requests:

The hardware Configuration shall be controlled by form, fit, function, interchangeability and interoperability, cost and schedule. All changes shall be controlled and changed using the contractors change process and engineering release process; however, proposed changes that impact the form, fit, function, interchangeability, interoperability, cost or schedule shall be submitted to the Government in accordance with the Contract data requirements. All contractor requests for changes to Turbine pump Assembly Performance Specification or Design Specification shall be submitted using ECPs as defined in ICE. The substantiating data shall present the impact of the configuration changes required to achieve conformance with Turbine pump Assembly Performance Specification or Design Specification.

Deviation:

A specific written authorization granted before the fact to depart form a particular Government-controlled requirement for a limited application.

Waiver:

Specific written authorization accepting a departure after occurrence from a Government-controlled requirement for a limited application.

All requested Deviation and/or Waivers shall require submittal and approval of the Government in accordance with the contract.

Configuration Status Accounting

All baselines, Engineering Changes Proposals (ECPs) Deviations and Waivers shall be documented in the contractors Configuration Status Accounting data base and in

Windchill in accordance with the data requirements documents in this contract. The purpose of CSA is to provide an up-to-date accounting of the exact configuration of each device. Status includes part numbers with appropriate revision levels, approved waivers and deviations, and incorporated or unincorporated Engineering Change Proposals (ECP's). This information is helpful to assure that the necessary logistic support elements can be correctly programmed in time to support the Configuration Item (CI). The contractor should be expected to review the data and assure its accuracy. The contractor should provide CSA information from the contractor's information system to the maximum extent possible.

Configuration Audits

The Functional Configuration Audit, FCA, and Physical Configuration Audit, PCA, are audits designed to verify, to the government, the accuracy and acceptability of the Functional and Product baselines and assure that the hardware is, in fact, built to these baselines. Hence, the FCA and PCA will be conducted by the government, with contractor support, prior to acceptance of a CI.

The Functional Configuration Audit is the responsibility of engineering and is conducted for each configuration item for which a separate development or requirements specification has been created. This audit verifies, for the government, the configuration item's performance against its configuration documentation.

The Physical Configuration Audit is the formal examination of the as-built configuration of a CI against its design documentation. Following successful completion of the PCA and the establishment of the Product Baseline (PBL). The PCA includes a detailed audit of engineering drawings, specifications, and ILS documentation.

3.3.7 Drawings and Associated Lists

Engineering drawings and associated lists for deliverable hardware shall be delivered to NASA and shall meet the requirements of ASME Y14.100 and ASME Y14.41 in accordance with DRD TVC4-CM-EDAL. In addition, Geometric Dimensioning and Tolerancing is required and shall be in accordance with ASME Y14.5M-1994. The Contractor shall deliver Pro-E compatible 3D models of deliverable hardware as requested by the COTR.

3.4 Reserved

3.5 System Analysis

3.5.1 Mass Properties Reports

Periodic Mass Properties Reports provide insight to the status of the mass properties of the program throughout all of its phases. The basis (Estimated, Calculated, or Measured) of each component mass shall be included as part of the recorded component data. Totals of each of these categories shall be recorded to provide an indication of the mass properties confidence. The Mass Properties report shall be submitted in accordance with DRD TVC4-SE-MPR Mass Properties Report. Periodic submittals of DRD TVC4-SE-MPR may be included as part of the Monthly Status Report as described in paragraph 1.2.2.

3.5.2 Analyses and Models

The Contractor shall perform analyses as necessary for the design and verification of the Actuator assembly. Analyses shall include, but are not limited to structural, thermal/fluids, and dynamic analyses. Analytical models developed under this contract shall be deliverable items. Fracture Control analyses shall be performed in accordance with the Upper Stage Structures Fracture Control Plan SO-CLV-DE-25104

3.5.3 Analysis Reports

The Contractor shall prepare reports on analyses performed for this contract. Reports shall be delivered as part of Design Review Packages, DRD TVC1-MA-DRP.

3.6 Turbine Pump Assembly Integration

The Contractor shall support NASA in the development of Interface Requirements Documents, Interface Control Documents and Instrumentation Lists for hardware. The turbine pump assembly has interfaces with Upper Stage Structure (thrust cone), Upper Stage Avionics, Upper Stage Engine and TVC hydraulics.

3.7 Operations

The Contractor shall develop an Turbine pump Assembly Operations Plan in accordance with DRD TVC4-SE-OPS. The plan shall define ground operations for the Engineering Model at locations including GRC, and MSFC, System Integration Laboratory. The plan shall also define operations for flight hardware including ground operations for Main Propulsion Test Article verification, prelaunch, launch and flight.

3.8 Technical Performance Measurement

The Contractor shall track key design performance parameters and report these values in the Monthly Status Report. These parameters shall include but not be limited to:

- Mass
- Volume
- Controller peak electric power consumption
- Controller average electric power consumption
- Rated Force
- Rated Velocity
- Stall force
- Turbine pump assembly stiffness
- Computer Processor Utilization
- Computer Memory Utilization
- Network Bandwidth Utilization
- Data Storage Utilization

4 TURBINE PUMP ASSEMBLY ENGINEERING MODEL DESIGN & FABRICATION

The Contractor shall design, develop, fabricate, and deliver 4 turbine pump assembly engineering models (with the option for 4 additional models) that meet the requirements as described in the Turbine pump Assembly Performance Specification. Analyses and tests shall be performed as part of the design and verification phase to assure compliance with requirements and, in the event of a test failure/anomaly, to identify probable causes and

corrective actions. Computer programs, data inputs, and data output utilized in these analyses must be documented and available to the Government upon request.

The turbine pump assembly design shall have the features, tolerances, dimensions and functions of a space-flight-rated unit. Non-space qualified components may be used in the Engineering Model provided a clear path to qualification can be outlined that is acceptable to NASA. The path must be consistent with the schedule for the production and qualification of flight hardware. The path to flight shall be reported in the Manufacturing and Assembly Plan, TVC4-MP-MP.

Major milestones for the Engineering Model include EM Final Design Review, EM Test Readiness Review, EM Pre Ship Meeting and EM Delivery.

4.1 Turbine Pump Assembly

The Contractor shall design and fabricate a turbine pump assembly that meets the requirements of the Turbine pump Assembly Performance Specification. Any deviations from the specification should be processed via an ECP.

4.2 Reserved

5 FLIGHT TURBINE PUMP ASSEMBLY DESIGN

The Contractor shall design the Ares I Upper Stage Turbine Pump Assembly, through Critical Design Review (CDR), that meets the requirements as described in the Turbine Pump Assembly Performance Specification, Attachment B.

Unless otherwise specified, the contractor shall design the Turbine Pump Assembly using best engineering practices such that mass is minimized, reliability is maximized, development risk is minimized, development cost is minimized, production cost is minimized, operating cost is minimized, and efficiency is maximized. Trade-offs among competing design goals shall be made in consultation with NASA.

Analyses shall be performed as part of the design and verification phase to assure compliance with requirements and, in the event of a test failure/anomaly, to identify probable causes and corrective actions. When computer analyses, including finite element analyses are used, deliverable information shall include a description of the analyses with applicable geometry, dimensions, loads, other boundary conditions, annotated input data file(s), plots of model geometry, and results. This information shall be sufficient to recreate the analysis if necessary. Computer programs, data inputs, and data output utilized in these analyses must be documented and available to the Government upon request.

Major milestones for the Flight Turbine Pump Assembly include Preliminary Design Review and Critical Design Review.

5.1 Turbine Pump Assembly

The Contractor shall design a turbine pump assembly that meets the requirements of the Turbine pump Assembly Performance.

5.2 Hydraulic Pump

The Contractor shall design a hydraulic pump that meets the requirements of the Turbine Pump Assembly Performance Specification

5.3 Reserved

5.4 Production Engineering and Planning

The Contractor shall submit a Manufacturing and Assembly Plan in accordance with DRD TVC4-MP-MP to define the objective, methods and procedures to be used in the manufacture and assembly of future production hardware and the Contractor's development and verification test units. The plan shall define the make-or-buy process, including objectives, criteria, management, logic, and results. This plan is used to establish the requirements for the Manufacturing and Assembly Plan so that the program can scope the entire magnitude of the task to be accomplished and provide technically sound, efficient, and cost effective plan of action to ensure projected schedules can be maintained. The Manufacturing and Assembly Plan shall identify long lead components and address plans for spare parts and assemblies to facilitate rapid repair. The plan shall also describe the path from non-space qualified parts that may be used in the Engineering Model to space qualified parts for the flight design.

The Contractor shall develop a manufacturing strategy facilitating the transition from development to production. The Contractor shall assume a production rate of 8 turbine pump assemblies per year for 25 years. Efforts to make the design more producible shall continue throughout the contract.

6 VERIFICATION AND VALIDATION

6.1 Verification Planning

The Contractor shall develop, document, and implement a Verification and Validation Plan, per DRD TVC4-VR-VP, that provides a detailed description of the project's verification/validation approach and structure for implementing the verification/validation program.

The Turbine pump Assembly Performance Specification shall be the basis of the verification and validation planning. Each requirement shall have a corresponding verification/validation requirement(s) that identifies how the requirement will be met. The verification/validation requirements shall be developed and documented in accordance with DRD TVC4-VR-REQ.

6.2 Engineering Model Verification

The Contractor shall be responsible for conducting all required testing associated with the Engineering Model turbine pump assembly, which includes development testing. The testing shall include, but is not limited to, functional performance tests, environmental thermal tests and vibration tests. The Contractor may assume that single axis testing is sufficient for verification of the Engineering Models. The Contractor shall:

- Prepare and submit development test plan per DRD TVC4-VR-DTP
- Prepare and submit an acceptance test plan per DRD TVC4-VR-ATP
- Submit test reports per DRD TVC4-VR-TR upon completion of tests.
- Provide all test support equipment.
- Provide and use a problem reporting system to document, track, and status problems.

The Contractor shall prepare and submit a verification compliance document per DRD TVC4-VR-VC that confirms the deliverable product, the engineering model, is in compliance with the specifications and is ready for a particular use, function, or mission.

6.3 Integrated TVC Subsystem Test Support

The Contractor shall support the NASA's in-house testing of an integrated TVC subsystem that will incorporate the turbine pump assembly engineering model. This support shall include up to 4 weeks of on-site assistance to support hardware installation, operations, data acquisition & electrical interfaces. The Contractor shall also supply information for test facility use, including installation instructions, operational requirements, and electrical & data interfaces.\

Appendix A – Acronyms

ACOTR	Alternate Contracting Officer's Technical Representative
ATP	Acceptance Test Plan
CDR	Critical Design Review
CI	Configuration Item
CIL	Critical Items List
CEV	Crew Exploration Vehicle
CM	Configuration Management
CMMI	Capability Maturity Model Integration
CMP	Configuration Management Plan
CO	Contracting Officer
COTR	Contracting Officer's Technical Representative
CSC	Computer Software Component
CSCI	Computer Software Configuration Item
CSU	Computer Software Unit
DM	Data Management
DPD	Data Procurement Document
DRD	Data Requirement Description
ECP	Engineering Change Proposal
EEE	Electrical, Electronic, and Electromechanical
EM	Engineering Model
FMEA	Failure Modes and Effects Analysis
GIDEP	Government-Industry Data Exchange Program
GRC	Glenn Research Center
ICD	Interface Control Document
ICE	Integrated Collaborative Environment
IV&V	Independent Verification and Validation
MSFC	Marshall Space Flight Center
NASA	National Aeronautics and Space Administration
OFT	Orbital Flight Test
PAP	Product Assurance Plan
PBL	Product Baseline
PCDU	Power Conversion & Distribution Unit
PDR	Preliminary Design Review
RID	Review Item Discrepancy
S&MA	Safety & Mission Assurance
SAP	Software Assurance Plan
SCM	Software Configuration Management
SOW	Statement of Work
SPDR	Software Preliminary Design Review
SRR	System Readiness Review
SRS	Software Requirements Specification
SWRR	Software Requirements

TIM	Technical Interchange Meetings
TRR	Test Readiness Review
TVC	Thrust Vector Control
WBS	Work Breakdown Structure