National Aeronautics and
Space Administration

John H. Glenn Research Center
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ATTACHMENT B PERFORMANCE SPECIFICATION FOR TVC ACTUATOR ASSEMBLY

RFP NNC06ZDD032R

Approval

DOCUMENT HISTORY LOG

REVISION LETTER	DESCRIPTION OF CHANGE	DATE	APPROVED
Initial	Initial Release of Specification		

TVC Actuator Assembly Flight Performance Specification—Draft Document

1. Background

This specification establishes the performance, design, development, and test requirements for the Thrust Vector Control (TVC) Actuator Assembly used for flight control actuation on the Upper Stage of Ares I (also known as the Crew Launch Vehicle). The purpose of this document is to provide potential proposers with a snapshot of the requirements as they currently stand; however, the exact values are subject to change as the vehicle configuration and/or mission evolves. These requirements may also be changed based on input from the Actuator Assembly Contractor or other Ares I Contractors.

Classification

This specification applies to Engineering Model hardware and Flight Production hardware. If there are differences between the Engineering Model and Flight Production specifications, they will be noted.

1.1. Mission Profile

Typical mission profiles for Ares I are provided in Figures 1 and 2.

Mission Profile – Lunar Mission (24 Aug 06)

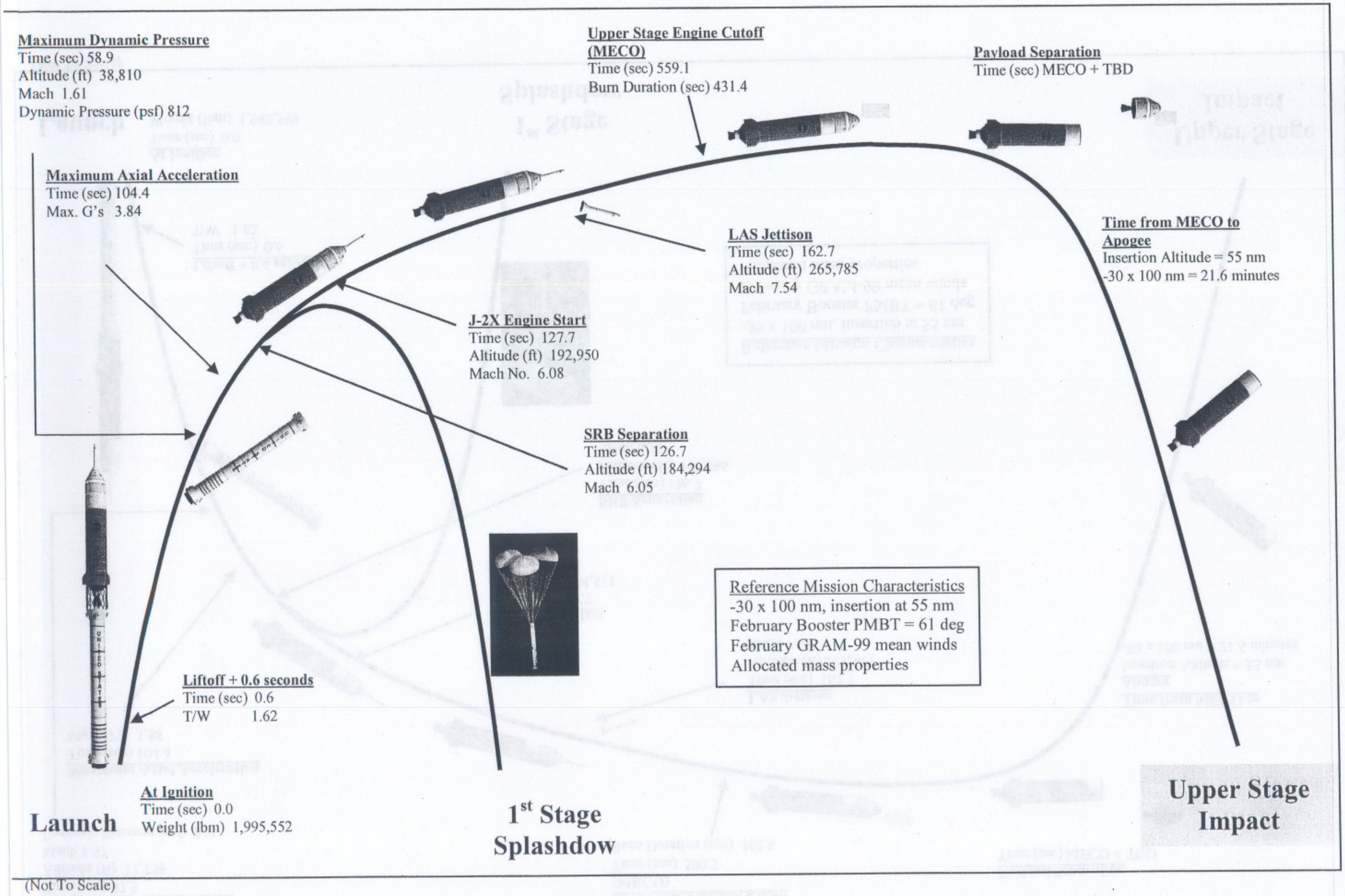

Figure 1. Ares I Lunar Mission Profile

Mission Profile – ISS Mission (24 Aug 06)

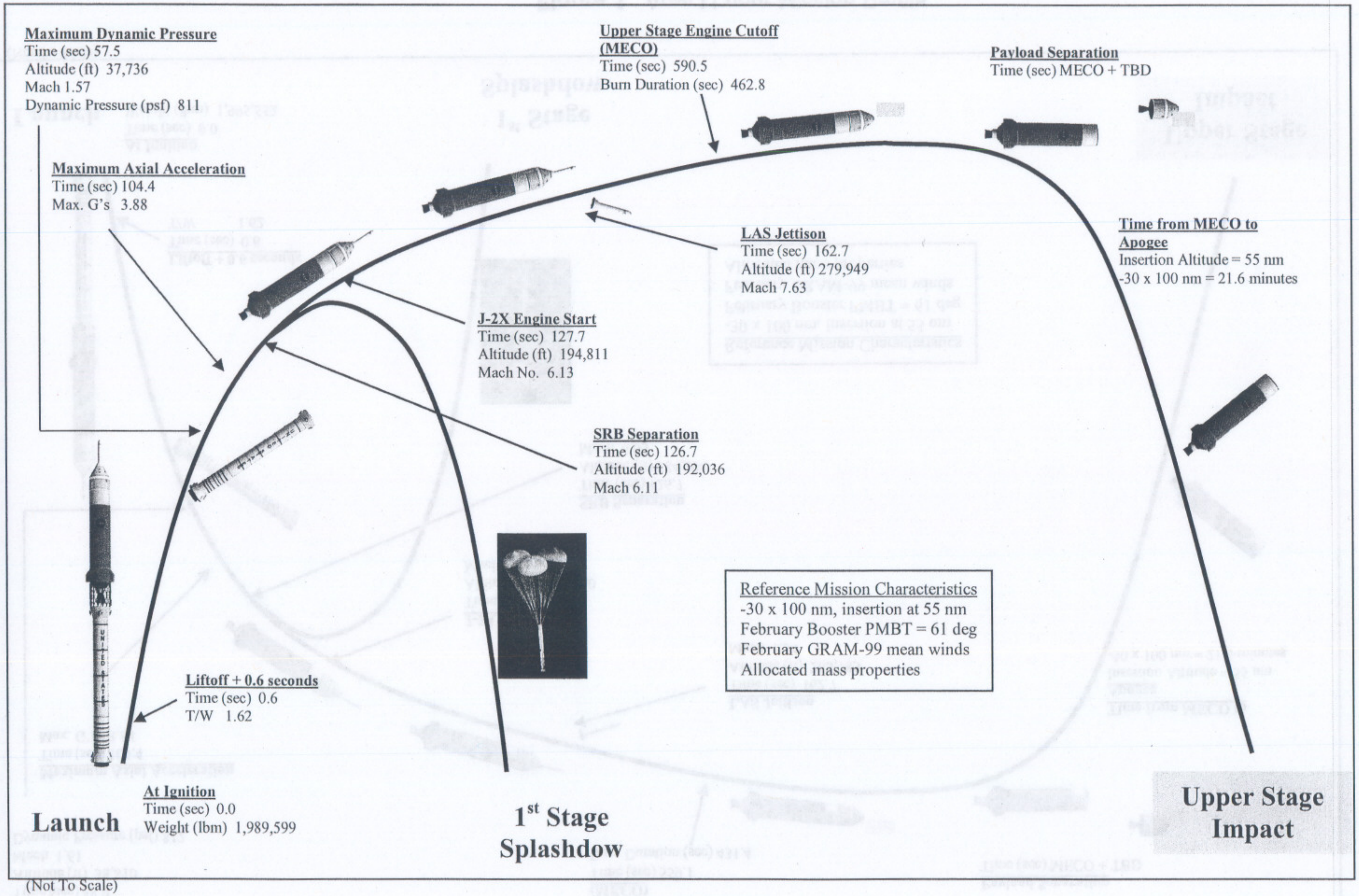

Figure 2. Ares I ISS Mission Profile

1.2. Actuator Assembly Coordinate System

The coordinate system has been specified for the Ares I with the X-axis in the longitudinal direction (vertical stacking axis).) as shown in figure TBD. Y and Z form the normal plane. TVC actuators gimbal the engine about the Y' and Z' (rock and tilt) axes.

2. Applicable Documents

2.1. Government Documents

The following documents (of the exact issue shown) form a part of this specification to the extent referenced herein. In the event of a conflict between the documents referenced herein and the contents of this specification, the contents of this specification shall be considered a superseding requirement.

STANDARDS

TBD

Table 1. Reference Documents TBD

3. Technical Requirements

3.0 Item Definition

The Actuator Assembly will provide the force and control to gimbal the J-2X engine of the Ares I upper stage. The assembly includes two four-channel electrohydraulic linear servoactuators, two actuator controllers, cabling with connectors between the actuators and controllers and associated software or firmware.

3.1. Physical Requirements

3.1.1. Interface Definition

The actuator assembly has interfaces with: 1) the Upper Stage Engine element, 2) other Upper Stage subsystems, and 3) other Thrust Vector Control assemblies

3.1.1.1 Engine Interfaces

Each actuator shall interface with the J-2X Ares I upper stage engine at the actuator lower attach points as shown in figure X.

3.1.1.1.1 Actuator Mounting Provisions

Actuator to engine mounting provisions are specified in figure TBD.

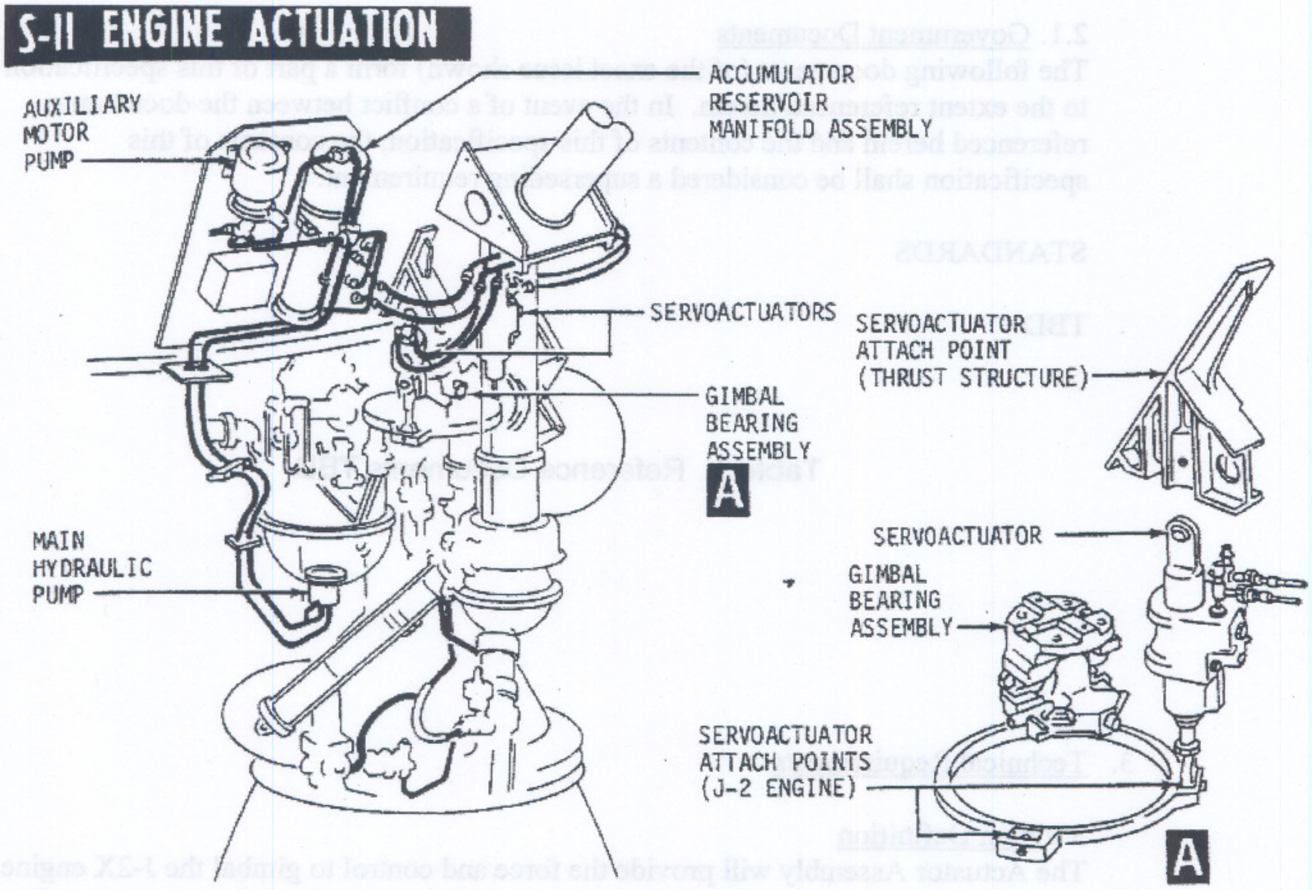

Figure X

3.1.1.2 Other Upper Stage Subsystem Interfaces

3.1.1.2.1 Interfaces with Structure

3.1.1.2.1.1 Structure to Actuator Interface
Each actuator shall interface with the Upper Stage thrust cone structure at the actuator upper attach points as shown in figure TBD.

3.1.1.2.1.2 Actuator Mounting Provisions
Actuator to structure mounting provisions are specified in figure TBD.

3.1.1.2.1.3 Structure to Actuator Controller
The actuator controllers shall be mounted to the Upper Stage thrust structure at the location shown in figure TBD.

3.1.1.2.1.4 Controller Mounting Provisions
The controllers shall be mounted to the structure as specified in figure TBD.

3.1.1.2.2 Interfaces with Avionics

3.1.1.2.2.1 Avionics to Actuator Controller
The actuator controller shall interface with the Upper Stage Avionics Subsystem for actuator commanding, actuator position feedback and actuator assembly health monitoring.

3.1.1.2.2.2 Interface Protocol
The actuator controller and Avionics Subsystem shall communicate via four redundant [TBR] Mil-Std-1553B channels. Each of the four channels will be dual redundant with the secondary bus in hot backup status.

3.1.1.2.2.3 Interface with Avionics Electrical Power Subsystem
The actuator Assembly shall receive primary and secondary 28 VDC power from Avionics Electrical Power Subsystem.

3.1.1.2.2.4 Power transfer
The transfer of Avionics EPS power to the actuator assembly shall not exceed the power profile in figure TBD.

3.1.1.2.2.5 Failure Notification.
The actuator assembly shall provide notification to Avionics within TBD milliseconds of a failure which could result in any of the following: loss of human life, loss of vehicle, or loss of mission.

3.1.1.3 Interfaces with the Thrust Vector Control Subsystem

3.1.1.3.1 Supply Pressure

The actuators shall meet all requirements while operating with a hydraulic supply pressure of 3000 psia +200, -0 and a return pressure of 100 to 50 psia.

3.1.1.3.2 Hydraulic Fluid

The actuator shall perform in accordance with the requirements herein when using hydraulic fluid conforming to MIL-H-83282.

3.1.1.3.3 Redundant Sources

The actuator shall accept pressure and return lines from two separate and independent hydraulic sources. The actuator shall meet all performance requirements when operating from either primary or secondary system. Ports for pressure and return lines shall be located as specified in figure TBD.

3.1.2 Physical Properties

3.1.2.1 Actuator Length

The TVC actuator shall be approximately 23-26 inches (pin-to-pin) in length.

3.1.2.2 Total Stroke

The actuator shall have a total stroke of 2.6 in. +TBD, -0.0 in.

3.1.2.3 Piston Rod Adjustment

The rod end shall be adjustable +/- 0.25 in increments of 0.07 in, maximum.

3.1.2.4 Overall Envelope

The actuator envelope shall not exceed the dimensions shown on figure TBD.

3.1.2.5 Actuator Assembly Mass

The total mass of the actuator assembly (2 actuators, controllers and cabling) shall not exceed 115 lbm.

3.1.2.6 Cable Length

The length of the cable between the actuator and the controller shall be 60 in.

3.2. Characteristics

The actuator shall be a double rod end type, with rod bearings on both sides of the piston. Piston areas on both sides of the piston shall not differ by more than 15%.

3.2.1. Assembly Performance

Unless otherwise specified, the actuator assembly shall meet the specified performance requirements under the following conditions:

a) All four channels uniformly commanded

b) Any three channels uniformly commanded with a hardover output in the remaining channel.

c) Any three channels uniformly commanded and a null output in the remaining channel.

d) With one or two systems pressurized at rated operating pressure.

3.2.1.1. Two-Axis Similarity

Both rock and tilt TVC actuators shall have identical capabilities.

3.2.1.2. Rated Load

The rated load of the actuator shall be 24,000 lb across the entire stroke range.

3.2.1.3. Peak Load

The actuator shall be capable of a peak load of 36,000 lb at stall conditions.

3.2.1.4. Rated Velocity

The actuator shall have a piston rod velocity capability of 2.4 in/sec (+/- TBD) at rated load.

3.2.1.5. Maximum Velocity

The maximum actuator piston rod velocity under no load shall not exceed 3.6 in/sec.

3.2.1.6. Acceleration Rate

The actuator must accelerate at a rate of TBD in/sec^2, with a load of TBD-slugs.

3.2.1.7. Resolution of Motion

The actuator assembly resolution of motion shall be 0.015 in including hysteresis, backlash, etc.

3.2.1.8. Structural Stiffness

The structural stiffness of the actuator, pin-to-pin, shall be no less than 600,000 lb/in (+/- TBD) with a pressure of TBD psi on each side of the actuator piston and with a fluid temperature of TBD deg.

3.2.1.9. Actuator Assembly Frequency Response

With the load and system characteristics defined by figure TBD, the frequency response of the inertia load shall be within the limits shown in figure TBD (Amplitude Ratio) and figure TBD (Phase Lag) for a no failed condition.

3.2.1.10 Transient Response

The position response to input signals as a function of time for conditions given in figure TBD shall fall within the limits of figure TBD.

3.2.1.11 System stability.
With system characteristics and block diagrams given in figure TBD, and actuator bias loads from 0 to stall load conditions, the load shall not have continuing oscillations, hunting, or limit cycling in excess of TBD in. peak-to-peak position during a 10 second period. Hunting or drift during a 1 minute period shall not exceed TBD.

3.2.1.12 Piston Leakage
The leakage past the piston seal with 3000 psi differential, shall be no more than 4 cubic inches per minute under static conditions.

3.2.1.13 External Leakage
Leakage past the rod end seals with 3000 psi differential, shall be no more than 4 drops in 100 full amplitude cycles.

3.2.1.14 Quiescent Leakage
With the actuator at null, with no external load and normal operating pressure applied, the quiescent flow shall not exceed TBD gpm at a hydraulic fluid temperature of TBD.

3.2.1.15 Reserved

3.2.1.16 Actuator Assembly Response to Channel Failures
TBD

3.2.1.17 Hydraulic Locks
The Actuator shall include locking valves that lock the piston in place when hydraulic pressure is lowered to TBD. If hydraulic pressure returns to normal, the locking valves shall open.

3.2.1.18 Servovalve Position Feedback
TBD

3.2.1.19 Thermal Control
The Actuator Assembly shall not require heating or cooling during flight.

3.2.1.20 Actuation Failure Mode
Preferred failure mode for the actuator is locked piston in last commanded position.

3.2.1.21 Hydraulic Filters
Hydraulic filters shall be provided to prevent failure of the internal components of the unit that are vulnerable to contamination. Filters shall be

employed where deemed necessary by the Contractor to fulfill the intent of the requirements herein.

3.2.1.22 Load Damping
A means of load damping shall be provided for piston position damping and frequency response as stated herein.

3.2.1.23 Mechanical Locks
A positive means shall be provided to mechanically lock the rod end to the piston end. The lock shall be removable.

3.2.1.24 Piston Bypass Valve
The actuator shall be provided with a piston bypass valve to enable manual positioning of the actuator rod end. The valve shall be manually operated. When operated, fluid locking of the piston will be relieved. The valve shall be pressure actuated to close at a supply pressure of 1000 psig maximum.

3.2.1.25 Response to Failures
The Actuator Assembly shall report health status to GN&C. GN&C will perform diagnosis and command the actuator assembly to bypass or disable failed parts, as applicable. This does not preclude the use of automatic functions such as hydraulic valve supply switching.

3.2.2. Electrical Design

3.2.2.1. Electrical Bonding and Grounding
The Actuator Assembly shall meet the electrical bonding requirements of NASA-STD-4003 as necessary in order to meet the E3 requirements of this document.

3.2.2.2. Instrumentation

3.2.2.2.1. Health and Status
The actuator assembly shall provide instrumentation to determine the health and status of the assembly. TBD

3.2.2.2.2. Actuator Position
The actuator assembly shall provide actuator position feedback to the GN&C at a rate of TBD as defined in the TVC /US IRD

3.2.2.3. Electromagnetic Compatibility
The Ares I TVC will tailor to MIL-STD-461E, "Requirements for the Control of Electromagnetic Interference (EMI) Characteristics of Systems and Equipment" to assist in establishing the Orion/Ares I requirements to meet the overall Electromagnetic Compatibility (EMC) requirements for the actuator

assembly. This tailoring will be documented in an Orion/Ares I Electromagnetic Environmental Effects (E3) Control Plan(s).

3.2.3. Failure Redundancies

3.2.3.1. Mechanical

3.2.3.1.1 Piston. The actuator may be single piston.

3.2.3.1.2 Seals. Dynamic seals shall be at least single fault tolerant. The volume between primary and secondary rod seals shall be vented to hydraulic return. A test port shall be provided between primary and secondary seals.

3.2.3.2. Hydraulic Supply Power

The actuator shall incorporate a switching valve to automatically switch external hydraulic sources from primary to secondary. The valve shall switch from primary to secondary within a pressure range of TBD in a falling system. The valve shall switch back from secondary to primary shall occur between a pressure range of TBD for a primary system with rising pressure

3.2.3.3. Actuator Servovalves

Four servovalves shall be provided for each actuator. Each servovalve will receive an input command from the actuator controller. Failed channels may be isolated. Electrical redundancy within each servovalve is not required.

3.2.4. Life Requirements

3.2.4.1. Actuator Assembly Life Cycle

The actuator assembly shall be designed for a combined flight and ground operation time of 250 hours after delivery without maintenance. Lifetime cycle loads, amplitudes and rates are defined in table TBD. Refurbishment of the seals and filters is permissible after 250 hours. Total operating life of the actuator assembly shall be 500 hours minimum.

3.2.4.2. Actuator Assembly Shelf Life

The actuator assembly shall meet or exceed a shelf life of 6 years without need for repair or refurbishment. [Applicable to Flight Design only.]

3.2.4.3. Actuator Assembly Pad Stay Time

The actuator assembly shall remain mission capable for up to 70 days while the vehicle is in the vertically mounted (fully stacked) configuration at the launch pad. [Applicable to Flight Design only.]

3.2.4.4. Integrated Space Vehicle Checkout

The actuator assembly shall allow for complete end-to-end static and dynamic functional verification testing in 30 minutes and without manual flight or ground system reconfiguration.

3.2.4.5. TVC Subsystem Servicing on Launcher—Pad Commodity Servicing
The actuator assembly shall not require any hazardous commodity servicing on the launcher or at the launch pad

3.2.4.6. Actuator assembly Servicing on Launcher—Pad Arms and Umbilicals
TBD

3.2.5. Maintainability

3.2.5.1. Scheduled Maintenance Allowance
The actuator assembly shall not require scheduled maintenance unless approved by NASA.

3.2.5.2. Replaceability
The actuator assembly shall be designed to allow a failed subassembly i.e.: the actuator or the controller or part, to be easily replaced.

3.2.5.3. Precluding Special Tools
The actuator assembly shall be designed so as not to require the use of special tools and equipment for site maintenance and repairs except as approved by NASA.

3.2.5.4. Requirements for Special Tools
Special tools, if required and approved by NASA, shall be designed to withstand the intended use for 20 years. The special tools shall be provided as GSE, in quantity TBD

3.2.5.5. Elimination of Potential for Misconnection
Where similar connectors are in close physical proximity, the design shall preclude the capability of cross-connection.

3.2.5.6. Elimination of Potential for Incorrect Installation
All unidirectional components shall be designed to preclude backward installation by using non-symmetry of configuration, different connector sizes, color coding, labeling or comparable means.

3.2.5.7. GSE (Ground Support Equipment) Attachments
Provisions shall be provided on the actuation assembly for attaching any necessary GSE for verification activities including lifting/handling and subsequent operation of the equipment.

3.2.5.8. Calibration and Adjustment
.The actuator assembly shall not require on-vehicle adjustments or calibration permitted except as identified and approved by NASA.

3.2.5.9. Reserved

3.2.5.10. Pre-Installation Acceptance and Checkout
The actuator assembly design shall accommodate acceptance checkout prior to installation.

3.2.5.11. Mounting and Installation
Mounting provisions shall permit actuator assembly removal and replacement by using standard hand tools.

3.2.5.12. Provisions for Visual Position Verification
The design of the actuator shall provide for visual verification of the actuator position with the actuator installed or removed from the vehicle.

3.2.5.13. Accessibility and Marking of Service and Test Ports
Servicing and test points shall be accessible and clearly marked. This is a flight design phase requirement.

3.2.5.14. Tool Clearances
The actuator design shall provide adequate tool clearances for all removable parts except as approved by NASA. This requirement shall include consideration of removal of the actuator assembly without removal of any other functioning hardware, plumbing, or wiring whenever practical. Wire bundle accessibility shall be provided without invalidating other wiring circuits or their related equipment. Accessibility to threaded fasteners will be accomplished without the use of universals, angular extensions, handle extensions, or combinations thereof, in conjunction with torque tools. This is a flight design phase requirement.

3.2.5.15. Protection Against Collateral Damage During Maintenance
Protection of subcomponents susceptible to damage during maintenance of the actuator assembly or adjacent equipment in the Upper Stage shall be provided to minimize risk of collateral damage

3.2.5.16. NDE Compatibility
Capability shall be provided to permit use of nondestructive evaluation (NDE) inspection equipment for fracture critical structural areas as defined by NASA.

4. Software Requirements

4.1. Language
TBD

4.2. Testing and Verification
TBD

5. Operational Requirements

5.1. Pre-Launch Check
The actuator assembly shall allow for a full range pre-launch gimbal check at the rated velocity.

5.2. TVC Actuator assembly
The actuator assembly shall be tested, calibrated, and certified by NASA and arrive at the launch site ready for upper stage vehicle Integration and integrated Ares I/Orion checkout.

5.3. Mission Duration
The actuator assembly shall be operational for the 600 second mission from launch to upper stage separation.

5.4. Position Holding
The actuator assembly shall hold the engine in the null position from launch until first stage separation.

5.5. Engine Start Transition
The actuator assembly shall provide sufficient holding force to prevent engine damage from excessive gimbaling during upper stage engine start.

5.6. Active Gimbaling
The actuator assembly shall begin active gimbaling immediately following upper stage engine start.

5.7. Gimbal Termination
The actuator assembly shall terminate gimbaling at upper stage separation.

5.8. Launch Delays
The actuator assembly shall be mission ready within 24 hours after a launch delay.

5.9. Launch Ready State
Actuator assembly servicing shall be complete prior to main propellant loading.

5.10. Automated Ascent Operations

The actuator assembly shall operate as a fully automated system (via US GN&C) from lift-command until CEV separation.

5.11. TVC Functionality During Ascent
The actuator assembly shall be fully functional while the Ares I is in the horizontal and/or vertical position.

5.12. Deleted

5.13. Horizontal Transport
The actuator assembly shall be able to hold the engine during any phase of horizontal transport to the launch site. Use of removable mechanical locks is permissible.

5.14. Vertical Transport
The actuator assembly shall be able to hold the engine during vertical transport to the launch pad. Use of removable mechanical locks is permissible.

5.15. TVC Launch Opportunities
The actuator assembly shall support a daily launch opportunity of not less than 4 consecutive days.

5.16. TVC Launch Ready State
The actuator assembly shall remain in a launch ready state for a period of not less than 2.5 hours.

6. Environmental Requirements

6.1. Flight Environment
The following environments are applicable to the flight operational performance requirements of the actuator assembly both individually and in any feasible combination. The actuator assembly shall perform as specified in section 3 of this specification during and after exposure to these environments.

a. Pressure — Maximum: TBD psia.
   1. Minimum: TBD Torr.
   2. Line Internal Transient: TBD psi/sec

b. Temperature — From minus TBD°F to plus TBD°F.
   1. Transient TBD°F to TBD°F at TBD°F per second

c. Random Vibration — Maximum random vibration occurs at liftoff, transonic, and qmax; and during main engine operation. These vibrations will not exceed the following:

Main engine burn for vehicle aft fuselage locations	Acceleration spectral density increasing at the rate of 6 dB/octave from 20 to 60 Hz; constant at 0.05 g2/Hz from 60 to 300 Hz; increasing at the rate of 6 dB/octave from 300 to 700 Hz; constant at 0.3 g2/Hz from 700 to 2000 Hz. The excitation occurs for a duration of 10 minutes per mission. The grms for the environment is equal to 21.3 grms.

d. Solar Constant — 443.7 Btu/ft^2/hour.

e. Rain (Surface to 32,800 ft) — Surface extreme rates of 19 inches in 24 hour period

1. maximum including short period extremes of four inches for one hour. Adjust for altitude as follows:

TABLE IX. Rain Correction for Altitude

Altitude (Ft.)	Percent of Surface Rate
0	100
3,280	90
6,560	75
9,840	57
16,400	15
26,240	1
32,800	0.1

f. Acceleration — +/- 5 g all axes.

g. Transient Vibration — Sinusoidal vibration from 5 to 35 Hz at +/- 0.25g and at the sweep rate of one octave/minute.

h. Altitude — The actuator shall operate from sea level to 400,000 feet

6.2. Checkout Environment

The following environments are applicable to the installed performance requirements of the actuator assembly both individually and in any feasible combination. The TVC shall perform as specified in section 3 of this specification during and after exposure to these environments.

External or Uncontrolled Areas:

a. Pressure — Maximum: TBD psia.
Minimum: TBD psia.

b. Temperature — From minus TBDºF to plus TBDºF.
Transient TBDºF to TBDºF at TBDºF per second

c. Sand and Dust — As encountered in desert and ocean beach areas, equivalent to 140-mesh silica flour with particle velocity up to 500 feet per minute and a particle density of 0.25 gram per cubic foot

d. Humidity — 8 to 100 percent relative humidity

e. Salt Fog — Salt atmosphere as encountered in coastal areas, the effect of which is simulated by exposure to a 1.0 percent salt solution by weight for 30 days.

f. Solar Radiation — Solar radiation of 377.6 Btu/ft^2/hour total normal incident.

g. Rain — Maximum of 19 inches in 24 hour period including short period extremes of four inches for one hour.

h. Hail — Hail (nominal) diameter equals 0.30 inches with a fall velocity of TBD

7. Safety
TBD

8. Quality Assurance

8.1. General Requirements

The Contractor is to submit a written Verification and Validation Plan for all program phases, to the Government for approval, as specified in the SOW.

8.1.1. General Verification Guidelines and Criteria

The contractor will use the following general guidelines in developing a verification program that shall satisfy the requirements of this specification:

a. Verification of transportation packaging performance shall be accomplished by analysis whenever possible. When verification by analysis cannot be accomplished, then testing shall be performed per the requirements in NPR6000.1 G.

b. Where new materials or existing materials under new conditions are to be used, adequate testing shall be performed to statistically identify material property values.

b. Application of non-destructive evaluation techniques shall be verified.

c. Verification shall be structured to verify the full range of the design requirements under the specified environments.

d. Wherever practical and technically sound, accelerated life test techniques shall be utilized.

e. Testing shall be conducted at the most cost effective level of assembly.

f. All verification test specimens shall be processed through specified acceptance testing prior to verification test.

g. Where redundancy in design exists, each redundancy shall be verified through normal output sources designed for that purpose.

8.1.2. Methods of Verification

Each performance and design requirement specified in Sections 3, 4 and 5 of this specification shall be verified by inspection, analysis, and/or test defined as follows:

8.1.2.1. Inspection

Verification by inspection is the process of determining compliance to requirements by the review of drawings, data, by examination (visual or visual with aid of NDE) of the item using standard quality control methods, without the use of special laboratory procedures. Inspection also includes evaluation of planning for assurance that considerations are made in the plan to address requirements. This is particularly applicable to the development phase.

8.1.2.2. Analysis

Verification by analysis is the process of utilizing analytical techniques to verify that the requirements are satisfied. Verification by analysis may be used when verification by test is not possible, introduces significant risk into the item, or is not cost effective. Analysis in conjunction with limited testing is an acceptable method where conditions dictate.

8.1.2.3. Test

Verification by test is a method in which technical means such as the use of special equipment, instrumentation, simulation techniques, and the application of established principles and procedures are used for the evaluation of components to determine compliance to requirements. Testing shall be selected as the primary verification method when analytical techniques do not produce adequate results. Tests may be used to support analytical techniques and to evaluate large range requirements where test of all conditions is not feasible or cost effective. The analysis of data derived from tests is an integral part of the test program and should not be confused with analysis defined in previous specification sections. Tests shall be used to determine quantitative compliance to requirements and produce quantitative results.

8.1.3. Verification Phasing

The verification of the actuator assembly will be structured coincident to the three main program phases, 1) Development, 2) Qualification and 3) Acceptance. The Verification matrix of TBD identifies the phase and verification method for each of the requirements of section 3, 4 and 5.

8.1.4. Development

This phase of the verification coincides with the development of the hardware prior to the Critical Design Review (CDR). This verification will establish feasibility of the proposed concepts to satisfy the design prior to authorization to make the flight qualification unit and begin qualification testing. The CDR package will constitute a large portion of the verification data for this phase.

8.1.5. Qualification

This phase of verification will coincide with the fabrication and testing of the qualification unit which will verify suitability of the post CDR baselined design with the requirements of this specification under the comprehensive environments and loads defined for the preflight ground and flight operations. The purpose here is to verify that the design meets the requirements of the specification. The first article (qualification unit) acceptance and the qualification test reports will constitute a large portion of this verification package.

8.1.6. Acceptance

The acceptance phase of verification will be performed on articles fabricated in accordance with the post qualification design baseline. The acceptance verification will be a subset of the qualification verification implemented in accordance with a cost effective and timely effort to assure compliance with the design baseline. The purpose being to verify that the hardware produced is in compliance with the design baseline. Each article produced will have a unique acceptance verification data package though the content will be similar or identical for each.

8.1.7. Test Conditions

8.1.8. Standard Test Conditions

Environmental standard test conditions for tests required by this specification shall be made at an atmospheric pressure of 28.5 plus 2 or minus 4.5 inches of Hg at a temperature of 73 plus or minus 18ºF and at a relative humidity of 50 plus or minus 30 percent.

8.1.9. Test Tolerances

Test tolerances shall be used as specified in MIL-STD-810 F as applicable except as follows:

8.1.10. Shock (acceleration vs. time)

Peak amplitude: +/-10 %
Pulse duration: +/-10 %

8.1.11. Acceleration

Specified acceleration: Plus 10 percent
Minus 0 percent

8.1.12. Measuring Instrumentation

Instrumentation sensitivity shall have one tenth of the tolerance specified for the parameter being measured and shall have current calibration per NIST.

8.1.13. Test Responsibility and Location

The seller shall be responsible for the performance of all inspections and tests. The contractor shall be responsible for implementing any quality assurance requirements. Except as otherwise noted, the seller may use his own facilities, government furnished facility, or any commercial laboratory acceptable to the buyer. NASA/GRC reserves the right to perform any of the inspections necessary to ensure conformance to the requirements of Section 3, 4, or 5.

8.2. Conformance Verification

8.2.1. Development

Development verification will be composed primarily of analyses and inspections of drawings and plans for the implementation of the development program. The development verification provides evidence that the proposed concept is in conformance to requirements and that plans and processes will assure quality control assurance against workmanship or material deficiencies. If the contractor builds and tests prototypes or engineering models in lieu of or to support the analyses these tests shall be performed in the sequence which provides assurance that the test results are representative of the article performance under the test conditions and are repeatable. The sequence identified in TABLE TBD is recommended to provide this assurance. It is advantageous that these tests and inspections shall be performed in a manner and under conditions, which simulate end use to the highest degree practicable however reasonable extrapolation of test results via analytical techniques is appropriate and allowed. Development verification shall include as a minimum those item described in TABLE TBD.

8.2.1.1. Inspections for Design Compliance

Inspection in the development phase will constitute a review of data presented as evidence that the conceptual design meets or at least addresses all of the requirements identified for verification at this phase of the project. Since the design will be immature, pre CDR, a complete compliance to a baseline design is not expected. It is however necessary for the data package to address all requirements particularly those associated with design features and functions. Assurance that the proposed concept is feasible will be goal of this activity. Alternative methods to be pursued as risk abatement is acceptable however each of the alternate concepts shall have feasibility for all requirements.

8.2.1.2. Inspections for Process Compliance

Inspections of the processes to be implemented in the Qualification and Acceptance phases will be performed to verify that the necessary level of quality control is provided to assure compliance and repeatability. All development phase verification requirements denoted as inspections in TABLE TBD Shall be addressed in the data package.

8.2.1.3. Development Analyses

The analyses provided for verifications will provide a high level of confidence that the proposed concept will result in compliance with requirements. Since the design is immature analyses may not be based on a final design configuration, however the risks associated with configuration changes must be quantified.

8.2.1.4. Development Tests

No specific development tests are required. Tests on prototypes or engineering models may be used to add validity to the analyses provided for development verification. Tests will be evaluated to a high level of scrutiny with respect to applicability to the proposed concept and its configuration. The controls and processes used in the test will also be subject to a high level of scrutiny.

8.2.2. Qualification

Qualification shall be performed in the sequence specified in TABLE TBD on all deliverable Qualification assemblies. This verification demonstrates conformance of the design to the entire range of end item requirements. Pre test inspections and functional tests will be used to provide quality control assurance against workmanship or material deficiencies for the test article. These pre Qualifications tests and inspections will include all planned Acceptance verification. These tests and inspections shall be performed in a manner and under conditions, which simulate end use to the highest degree practicable, affordable and feasible with the understanding that the Qualification article may be used up at the end of the Qualification program. The sequencing provided in the table and the Qualification test planning will take this life limited aspect into consideration with the assumption that only one Qualification unit will be used in the program. The degree, duration, and number of tests and pre/post test inspections shall be sufficient to provide assurance that the quality required is present prior to and maintained throughout the verification activity. Qualification shall include as a minimum those item described in TABLE TBD. In addition the contractor shall identify and perform those other pre Qualification tests deemed necessary by the contractor to ensure successful evaluation of the test item.

8.2.2.1.Qualifications Inspections

Qualification inspections shall be used to verify that the qualification unit is in compliance with the baselined design, manufacturing and procurement requirements as defined in the drawings and specifications. Inspections shall be made to the process paperwork to assure that all quality assurance provisions have been implemented in the test program procedures. All test equipment used in the test program will be inspected to assure compliance with the test program plans and procedures.

8.2.2.2.Qualification Analyses

Analyses used as part of Qualification shall provide undisputable evidence that the design is in compliance with the requirements of this specification. If necessary, analysis combined with test results may be combined to provide this evidence. Every aspect of, and the entire range of environments and loads will be addressed by analysis or an actual test. Analyses will be traceable to the paragraphs of this specification and the specific revision level of the design drawings and related documentation.

8.2.2.3.Qualification Tests

8.2.2.3.1. Qualification Test Hardware

Qualification test hardware shall be of the same configuration as the delivered flight hardware. All Qualification testing shall be performed on a single serial number unit unless otherwise necessary based on life requirements and otherwise approved by NASA. Spare or additional qualification units may be incorporated into the test program as provided by the statement of work to mitigate risk due to loss of unit, i.e. unrecoverable failure of the qualification unit, during testing, and only with the written approval of NASA.

8.2.2.3.2. Performance Tests

The functional performance tests on the actuator shall be tested in flight configurations and under flight environments. As a minimum these tests shall include nominal, and worst case environment functional tests for each of the requirements identified in TABLE TBD.

8.2.2.3.2.1.Vibration Test

Perform vibration tests on the actuator as specified below:

Vibration Test information TBD.

8.2.2.3.2.2.Life Cycle Test
The actuator assembly shall be designed to meet TBD total cycles applied as follows:

1. With the actuator mounted on a load fixture permitting the application of constant reversing loads:

    a. Apply TBD cycles at full actuator strokes cycling at the maximum hydraulic power output point of the servo-valve. At the completion of cycling disassemble the actuator and examine the seals. Replace if necessary.

    b. Apply TBD cycles at one half full actuator stroke cycling at one half the maximum hydraulic power output point of the servo-valve. At the completion of cycling disassemble the actuator and examine the seals. Replace if necessary.

2. With the actuator mounted on a load fixture simulating structural compliance and engine mass apply TBD cycles as follows:

    Apply constant amplitude sinusoidal command signals to the servoloop equivalent to a DC actuator displacement of 1% and 25% each for a duration of 8 minutes at the following frequencies; 0.2, 0.4, 0.6, 1.0, 2.0, 2.5, 3.0, 3.5, 7.5, 8.0, 8.5, 9.0, 10.0, 12.0, 16.0, and 20.0 cps.

    NOTE: A diametral clearance of 0.004 in maximum between the inner and outer races of the actuator end bearings in permissible after TBD cycles as defined above. Clearance is to be measured using a 5.5 pound reversing load. Clearance is to be measured at 25,000, 50,000, 100,000, and 150,000 cycles.

8.2.2.4.Weight
The test actuator assembly shall be weighed and recorded in lbs to 2 decimal places.

8.2.2.5.<u>Identification of Center of Gravity (CG) and Moment of Inertia</u>
The test actuator assembly shall have the CG and moment of inertia measured in inches to 2 decimal places.

8.2.2.6. Post Test Inspection

Disassemble and visually inspect the actuator. Record any evidence of degradation, contamination, and/or excessive wear.

8.2.2.7. Explosion Proofing

The actuator shall pass explosion proofing test in accordance with MIL-STD-810 F method 511.4.

8.2.2.8. Lifting Equipment Proof Test

Lifting equipment GSE for the actuator assembly handling shall be proof tested in accordance with requirements of NASA-STD-8719.9.

8.2.2.9. Electrical Protection Devices

Electrical protection devices shall be tested before use to verify intervention when power is applied in reverse polarity. This test shall be performed before application of power to the test unit.

8.2.2.10. NDE Compatibility

The test actuator shall be subjected to Non-Destructive Evaluation (technique to be selected by GRC/NASA) for compatibility assessment.

8.2.3. Acceptance

Acceptance verification shall be performed in the sequence specified in TABLE XVII on all deliverable assemblies. This verification demonstrates conformance to requirements and provides quality control assurance against workmanship or material deficiencies. These tests and inspections shall be performed in a manner and under conditions, which simulate end use to the highest degree practicable without damage to the assemblies. The degree, duration, and number of tests and pre/post test inspections shall be sufficient to provide assurance that the quality required is present prior to and after Acceptance verification. Acceptance verification shall include as a minimum those item described in TABLE TBD. In addition the contractor shall identify and perform those other tests deemed necessary by either the contractor or NASA to ensure successful operation of the deliverable assemblies.

TABLE XVII. Acceptance Verification Sequence

Test	***Sequence Order***
Examination of Product	1
Ambient Functional	2
Design Features	3

8.2.3.1. Examination of Product

Each actuator assembly shall be carefully examined to determine conformance to the requirements of this specification. Particular attention shall be given to valve performance, weight, workmanship, finish, dimensions, construction, cleanliness, identification markings, traceability level, and that certified materials and processes have been used. Locking inserts shall be individually inspected to verify proper installation.

9. Delivery Requirements

The requirements specified herein govern the preparation for shipment and the transport of the item to all Government facilities. The methods of preservation, packaging, and levels of packing used for shipment, together with the necessary special control during transportation, shall be in accordance with NPR6000.1 G. The item shall adequately be protected from damage and degradation of performance due to the natural and induced environments encountered during transportation and subsequent storage.

9.1. Preservation Requirements

Preservation methods shall include the application of protective measures and materials to maintain the item within the appropriate cleanliness levels and to prevent damage or degradation in reliability or performance of the item when exposed to the natural and induced ground based transportation and ground handling environments. The requirements for preservation methods and levels of protection shall be in accordance with NPR6000.1 G.

9.2. Packing Requirements

Packing shall include special design containers used for the transportation and storage of the item. Packing shall be used in conjunction with the appropriate preservation methods, handling procedures, and methods of transport to prevent damage or degradation in reliability or performance of the item when exposed to the natural and induced ground based transportation and ground handling environment. Packing requirements shall be in accordance with NPR6000.1 G. and supplemented by the following paragraphs.

9.3. Monitoring Devices

Use of instrumentation for monitoring or recording in-transit environments (e.g. shock, vibration, temperature, etc.), shall be approved by GRC prior to implementation.

9.4. Packaging of Precision Clean Items

Prior to packaging in accordance with NPR6000.1 G, items cleaned to the level of cleanliness specified in paragraph 3.3 shall first be pre-packaged to assure maintenance of the prescribed cleanliness level. Materials and methods of packaging shall be in accordance with MSFC-SPEC-164 B.

9.5. Temporarily Installed Hardware Identification

All temporarily installed devices such as caps, plugs, covers, support bracketry, protective plates, etc., shall be highly visible, red in color or shall have attached highly visible red colored streamers to ensure that they are easily identified under casual observation.

9.6. Marking for Shipment

Interior and exterior containers shall be marked and labeled in accordance with NPR6000.1 G and MIL-STD-129 P including precautionary markings necessary to ensure safety of personnel and facilities and to ensure safe handling, transport, and storage. NASA Critical Item Label (NASA Form 1368) shall be applied in accordance with NPR6000. The following identification information on interior and exterior containers shall include as a minimum:

a. NASA Contract Number
b. Item Name
c. Manufacturer's Part Number
d. Serial Number
e. Manufacturer's Name
f. Manufacturer's Cage Code Number
g. Quantity
h. Cleaning Marking – Add the words "THIS PART HAS BEEN CLEANED TO LEVEL ______ OF MSFC-SPEC-164 B."
i. Gross Weight

10. Notes

10.1. Definitions

10.1.1. Design Burst Pressure

Design burst pressure is the maximum operation pressure multiplied by the design factor of safety.

10.1.2. Failure

The inability of a system, system, component, or part to perform its required function within specified limits and under specified conditions for a specified duration.

10.1.3. Limit Pressure

Limit pressure is the maximum differential pressure to which the structure will be subjected under specified conditions of operation. Limit pressure is defined as the relief valve nominal pressure plus its tolerance and plus hydrostatic head.

10.1.4. Operating Cycles

The cumulative number of times an item completes a sequence of activation and return to its initial state; e.g., a switched-on/switched-off sequence, a valve-closed/valve-opened sequence, a tank pressurized/depressurized.

10.1.5. Operating Life

The specified operating time/cycles which an item can accrue before replacement or refurbishment without risk of degradation of performance beyond acceptable limits.

10.1.6. Shelf Life

The period of time, during which an item can remain in storage without having its operability affected. Preventive maintenance, servicing, and replacement of age-sensitive material and parts shall be permitted on a scheduled basis during the storage period.

10.1.7. Ultimate Factor of Safety
The ultimate factor of safety is applied to the specified limit loads to produce design loads which, when exceeded, would result in failure of the structure.

10.1.8. Useful Life
The item's total life span including operating life and storage with normal preventive maintenance, servicing, repair, and replacement of parts before item is considered unacceptable for further usage. This life span may be equal to (throw away), or greater than (repair, refurbish, etc.) the specified operating life.

10.1.9. Yield Factor of Safety
The yield factor of safety is applied to the specified limit loads to provide design loads which, when exceeded, would result in permanent deformation of the structure.

10.1.10. Batch/Lot
A batch or lot is defined as all material manufactured in one continuous production run or lot of each ingredient.

10.2. Abbreviations and Acronyms
Abbreviations and acronyms used in this specification are defined as follows:

A	Analysis
CDR	Critical design review
CEV	Crew Exploration Vehicle
CG	Center of Gravity
db	decibel
dc	Direct Current
E	Exempt from Traceability
E3	Electromagnetic Environmental Effects
ECF	Environmental Correction Factor
EEE	Electronic/Electrical/Electromechanical
ELP	Electrical Power Loss
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
F	Fahrenheit

ft	Foot or feet
ft^2	Square foot or feet
g	Gravity
GN2	Gaseous nitrogen
GN&C	Guidance Navigation & Control
GSE	Ground Support Equipment
He	Helium
H_2	Hydrogen
Hg	Mercury
hr	Hour
Hz	Hertz (cycles per second)
I	Inspection
lb	Pound
lbm	Pound mass
lbf	Pound force
LRU	Line Replaceable Unit
MEOP	Maximum Expected Operating Pressure
MSFC	Marshall Space Flight Center
NA	Not applicable
NASA	National Aeronautics and Space Administration
NDE	Non-destructive evaluation
NIST	National Institute of Standards and Traceability
N_2	Nitrogen
O_2	Oxygen
psi	Pounds per square inch
psia	Pounds per square inch absolute
psid	Pounds per square inch differential
psig	Pounds per square inch gauge
rms	Root mean square
SCCS	Standard cubic centimeters per second
SCIM	Standard cubic inches per minute
sec	second
STD	Standard
T	Test
TBD	To be determined by buyer or seller after award of contract

TBS	To be supplied
Ts	Serial traceability
T_L	Lot Traceability
vdc	Volts direct current
vs	versus