Exploration Launch Office

Upper Stage Request for Information

March 20, 2006

Introduction

The National Aeronautics and Space Administration invites Industry to submit a response to this inquiry to assist NASA in the planning for the Crew Launch Vehicle (CLV) Upper Stage Element acquisition development. The information contained herein represents the current program content. Industry response to this Request For Information (RFI) is requested within the context of the general approach described in the following paragraphs.

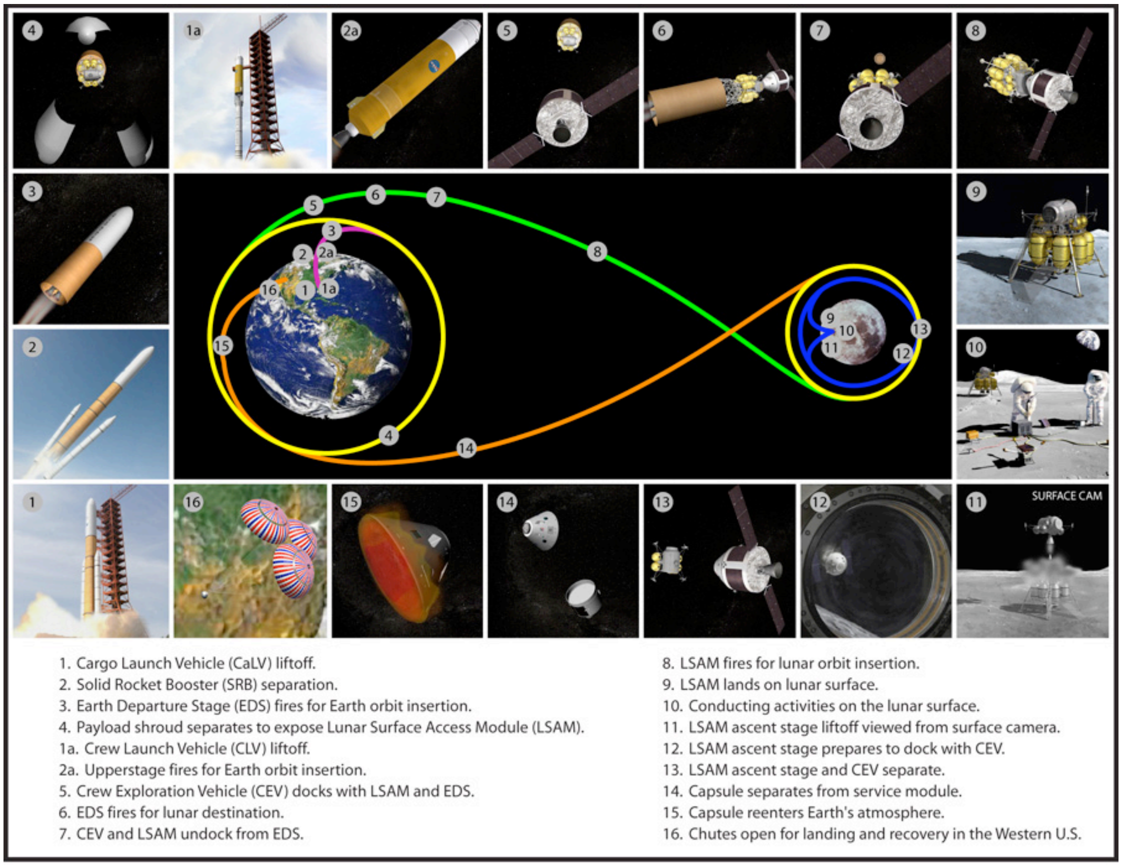

Figure 1.0 Constellation Architectures

The Exploration Systems Mission Directorate (ESMD) Constellation Program is responsible for developing the Crew Exploration Vehicle (CEV), Crew Launch Vehicle (CLV), Cargo Launch Vehicle (CaLV) and related exploration architecture systems that will provide humans the capabilities necessary to travel and explore the solar system as illustrated in Figure 1.0. The CEV is the spacecraft that NASA plans to use to send human and cargo items into space and to return them to Earth. The human-rated CLV, shown in Figure 2.0, will deliver the Crew Exploration Vehicle (CEV) to low-Earth orbit early next decade. The CLV is an in-line configuration with a 5-segment Reusable Solid Rocket Motor (RSRM) as the First Stage and a new Upper Stage powered by a liquid hydrogen / liquid oxygen J2X engine, an evolution from the Apollo program's Saturn IB and Saturn V.

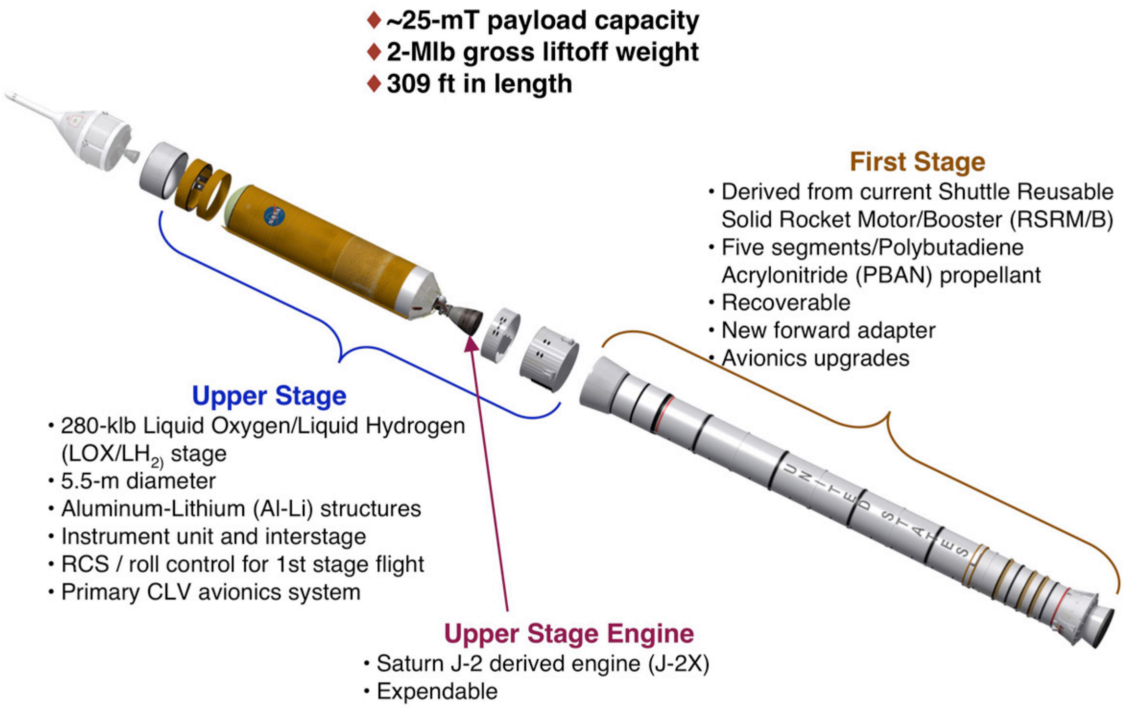

Figure 2.0 Crew Launch Vehicle

From its initial position in low-Earth orbit, the CEV has the capacity to either continue on to the International Space Station or to dock with an Earth Departure Stage (EDS), launched separately on NASA's heavy-lift Cargo Launch Vehicle (CaLV). The EDS will provide the navigation and propulsion necessary to execute a Lunar mission as illustrated in Figure 3.0. While each of these elements will play a major role in the execution of the Nation's Vision for Space Exploration, this Request For Information (RFI) will focus solely on the acquisition and development of the CLV Upper Stage. Additional information describing the Agency's vision for space exploration and its plans for the acquisition and development of each major element can be found on the Exploration Systems Mission Directorate website (http://exploration.nasa.gov).

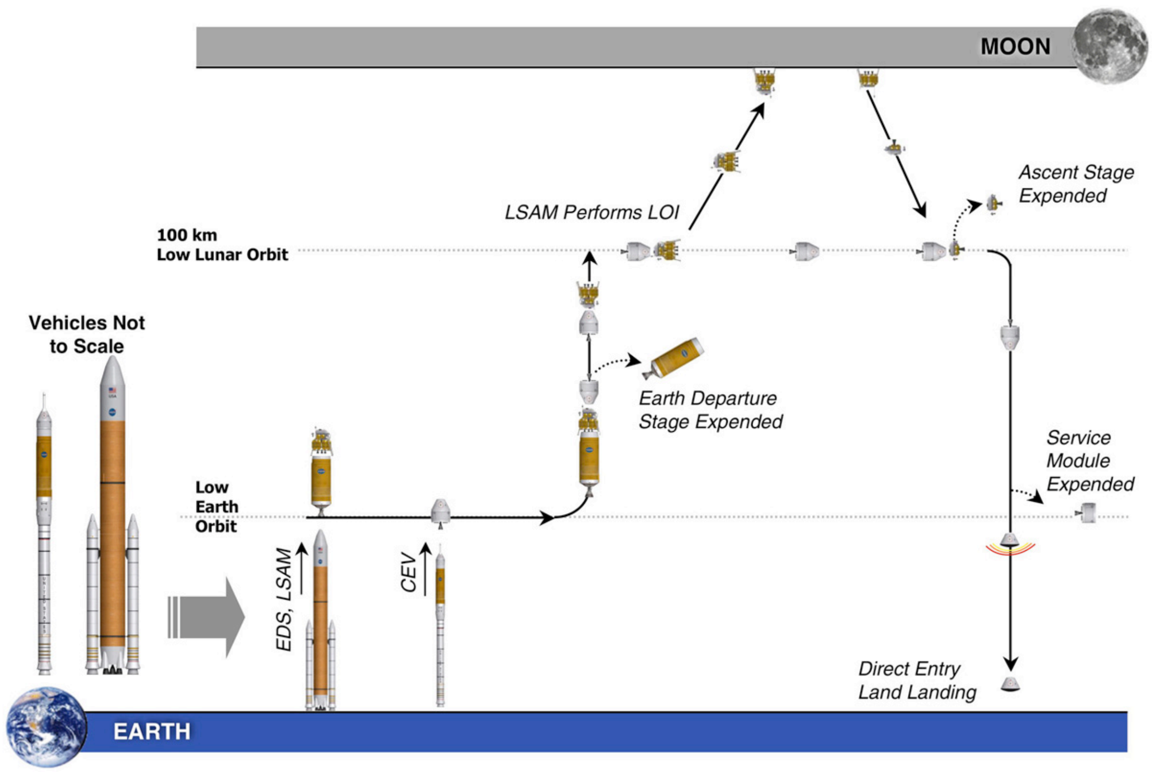

Figure 3.0 CEV Lunar Mission Scenario

NASA plans to lead a substantial in-house effort to develop the requirements, design, and testing required to deliver integrated Upper Stage(s) to the Kennedy Space Center. The final integrated Upper Stage will be the product of numerous partnerships among industry participants and NASA, for the delivery and operation of the integrated Upper Stage. NASA plans to maintain data rights on the design and the resulting Upper Stage hardware. The following paragraphs provide a top-level overview and description of the Upper Stage and its primary sub-systems, and describe the Agency's planned development, manufacturing and operation approach for the CLV Upper Stage. The configuration described below is the current Upper Stage design chosen as a baseline for conceptual design and trade study. Changes to configuration and element function are expected as the design matures.

Crew Launch Vehicle Upper Stage Description

The CLV Upper Stage, including the Upper Stage Engine, as shown in Figure 2.0, will provide the navigation, guidance, control and propulsive impulse required for the second phase of the CLV ascent flight after the First Stage separates from the launch vehicle. This includes the main propulsion system with thrust vector control, a reaction control impulse for attitude roll and pitch control and separation systems required to perform First Stage separation. The self-supporting cylindrical structure measures approximately 996 inches long from the Instrument Unit to the Interstage, and is approximately 216.5 inches in diameter. The Upper Stage configuration and performance is based on the top-level driving requirements listed in Table 1.0. The Upper Stage engine will be provided to the Upper Stage Production contractor as Government Furnished Equipment for final installation into the integrated Upper Stage at the Michoud Assembly Facility prior to shipping the stage to KSC for launch vehicle integration and stacking.

- **Configuration Mass**
  - Stage Dry Wt (J-2 & US) 31,545 lbm
  - US Allocation 22,996 lbm
  - Interstage Allocation 8,454 lbm
- **Propellant Inventory**
  - Usable Propellant 282,345 lbm
  - Usable Propellant LH2 43,438 lbm
  - Usable Propellant LOX 238,907 lbm
  - Mixture Ratio 5.5 nom
  - Reserve Propellant 1%
- **SRM&QA**
  - Redundancy FO/FO/FS
- **Performance**
  - Start Boxes Assume J-2
  - NPSH LOX (approx) 43 ft (TBR)
  - NPSH LH2 (approx) 220 ft (TBR)
  - Expected Tank Press 50 psia max
- **Avionics**
  - Design for Earth Departure Stage (EDS)
- **Flight Termination System**
  - Required
- **TVC Duty Cycle**
  - Max Gimbal Angle +/- 6
- **Autogenous Press Gas Properties**
  - Assume J2-S Flow properties
- **Commodity Supply**
  - Helium Supply Assume J2
- **Engine Parameter**
  - Thrust (Nominal) 293k lbf
  - Engine length 185 inches (TBR)
  - Engine Diameter 120 inches (TBR)
- **Loads**
  - Per Feb 10, 2006 update
- **Roll Control**
  - Boost Phase TBD ft-lbs
  - 2nd Stage Phase TBD ft-lbs

Table 1.0 Upper Stage Preliminary Key Requirements

The Upper Stage Core, as shown in Figure 4.0 consists of the following primary elements and their respective sub-systems: Forward Skirt, Liquid Hydrogen Tank, Intertank, Liquid Oxygen Tank, Aft Skirt, Thrust Structure, Main Propulsion System, Thrust Vector Control, Systems Tunnel, Purge and Vent System and a Separation System.

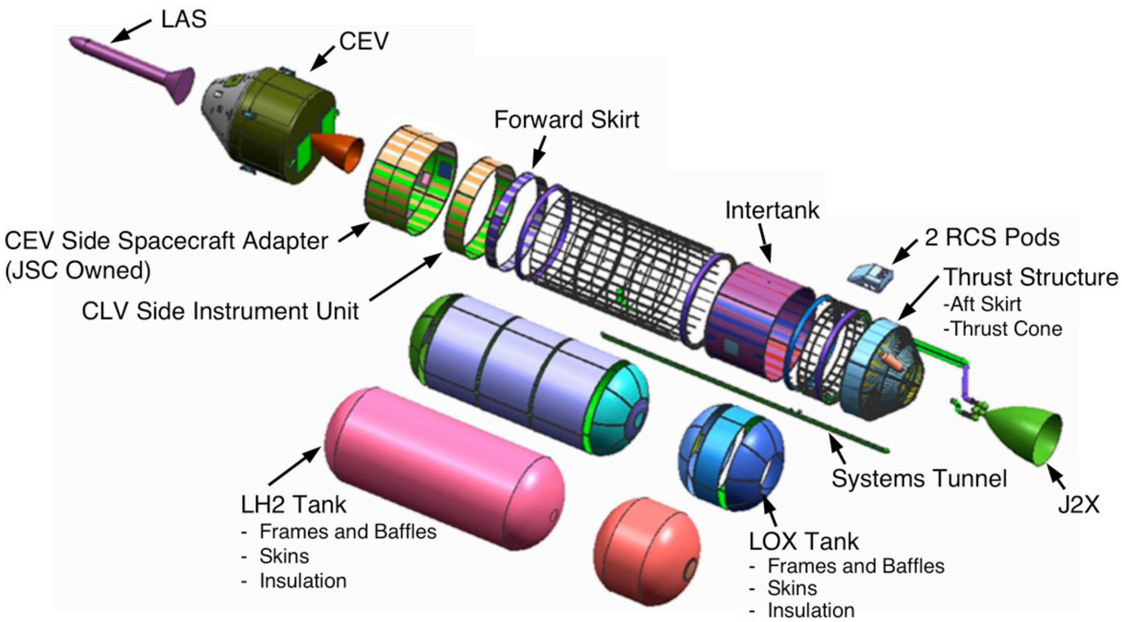

Figure 4.0 Upper Stage Core Primary Elements

The Forward Skirt will provide an area for the systems tunnel egress, an area for the liquid hydrogen tank venting and a purge to the enclosed volume of the CEV service module and the Instrument unit. The forward skirt, a 216.5-inch diameter cylinder measuring approximately 26 inches in length, will be fabricated from 2195 aluminum-lithium alloy.

The Liquid Hydrogen tank, approximately 400 inches in length and 216.5 inches in diameter, will be a friction-stir welded assembly constructed from 2195 aluminum-lithium alloy. The tank assembly will consist of a forward and an aft ellipsoidal dome, three cylindrical barrel-sections, ring frames, Y-rings and a slosh baffle assembly. The Liquid Oxygen tank will also be a friction-stir welded assembly constructed from 2195 aluminum-lithium alloy. It will consist of a forward and an aft spin-formed dome caps, stretched formed gore domes (aft & forward), extruded Y-rings, 6 rolled barrel panels, slosh baffle assembly and an anti-vortex baffle and sump assembly. Both tanks will be load bearing and will require the application of a thermal protection system for cryogenic fluid management. Figure 5.0 illustrates the current conceptual configuration and subsystem layout for the liquid hydrogen and liquid oxygen tanks.

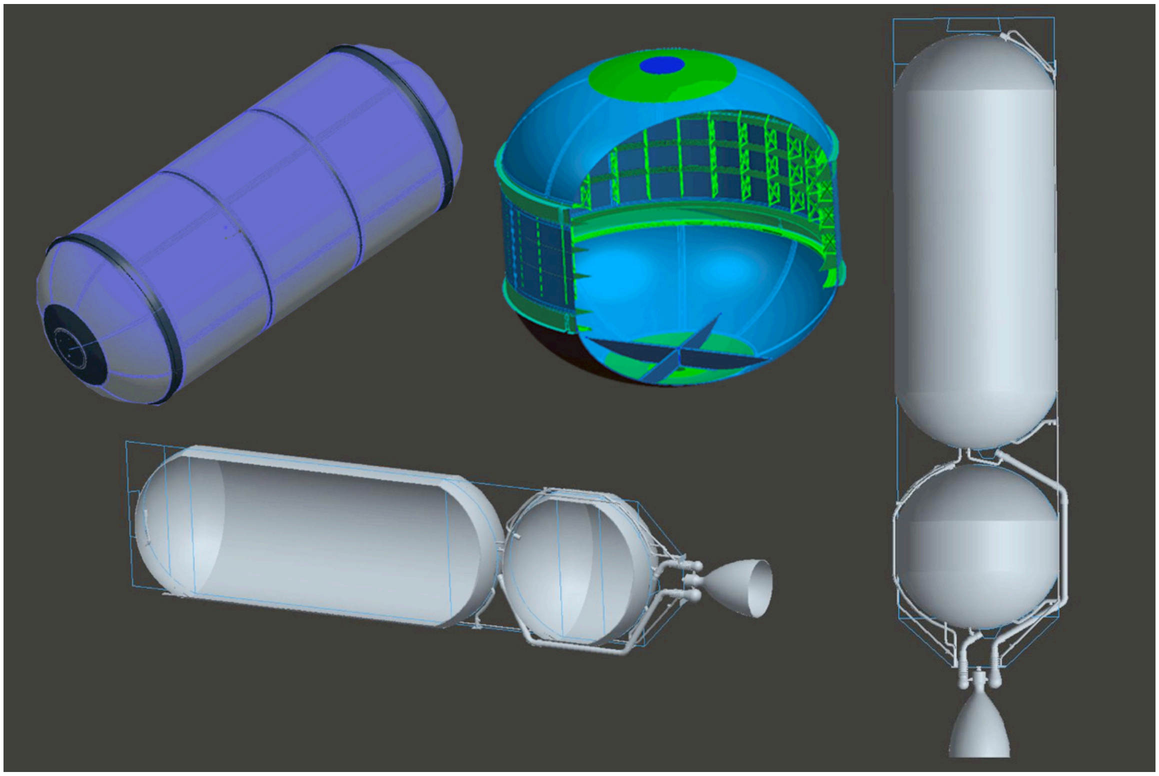

Figure 5.0 Liquid Hydrogen / Liquid Oxygen Feed System Concepts

The Intertank, measuring approximately 149 inches in length and 216.5 inches in diameter, serves as the structural interface between the liquid hydrogen and liquid oxygen tanks. It will also be constructed from a machined orthogrid 2195 aluminum-lithium alloy. The intertank contains a purge umbilical and feed line umbilicals for both tanks.

The Upper Stage Thrust Structure assembly, shown in Figure 6.0, includes the aft skirt and the thrust cone and will accommodate the Upper Stage RCS system, the Upper Stage engine and the interface to the Thrust Vector Control (TVC) system. The aft skirt and the thrust cone measure approximately 216.5 inches in diameter and are 49 inches and 66 inches in length respectively, and are both constructed from 2195 aluminum-lithium alloy. The four aft skirt isogrid panels are welded together using friction-stir welding techniques, and the four thrust cone panels are a machined skin-stringer construction. The thrust cone will be constructed with cross beam for engine mounting and provide reaction support for the TVC system.

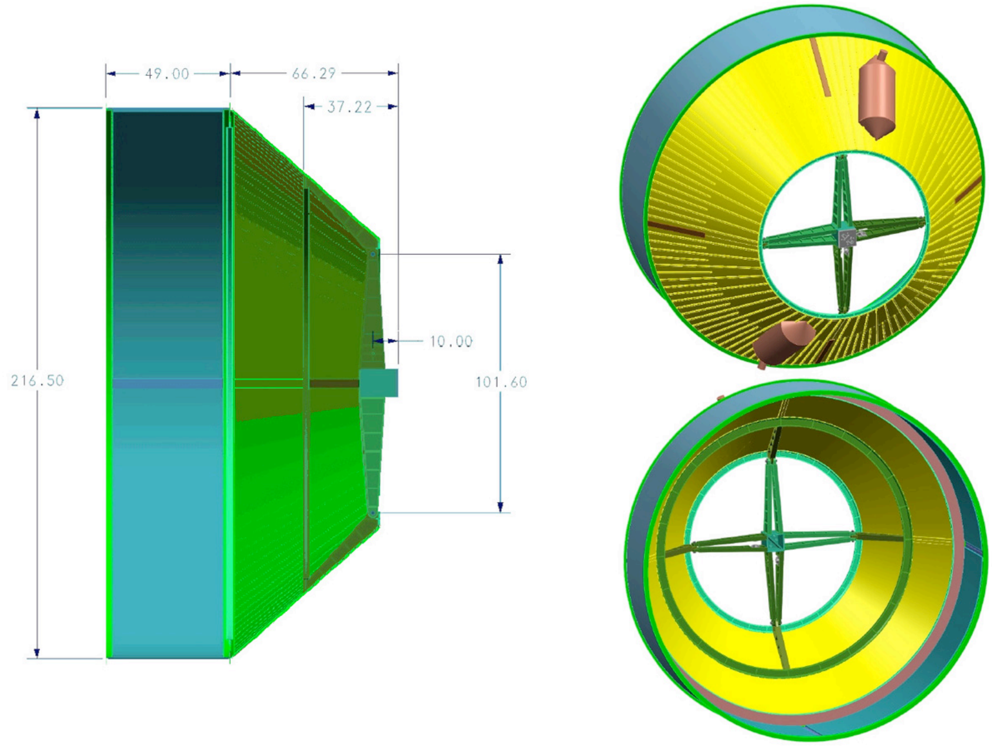

Figure 6.0 Upper Stage Thrust Structure Concept

The Upper Stage Main Propulsion System (MPS) includes the hardware necessary to supply liquid hydrogen and liquid oxygen to the Upper Stage Engine and the commodities for engine control and conditioning. It will consist of the liquid oxygen, liquid hydrogen, and the pressurization and pneumatic subsystems.

The Upper Stage Thrust Vector Control (TVC) system will provide vehicle attitude and trajectory control during ascent after First Stage separation. During the First Stage ascent phase, the Upper Stage engine will be commanded and gimbaled to the null position to prevent damage by shifting. The TVC system, as shown in the schematic in Figure 7.0, will include two Electro-Mechanical Actuators (EMAs) mounted perpendicular to each other to provide vehicle pitch and yaw control capabilities and two separate power and drive systems that are provided to supply a single fault tolerant system up to the actuators. The two power systems are cross-strapped such that failure of any component in one system allows for switching to the other power system. 270 VDC batteries supply the electrical power for the actuators. Each battery has enough reserve power to supply both actuators throughout the mission duration and redundant actuator controllers are provided for each EMA.

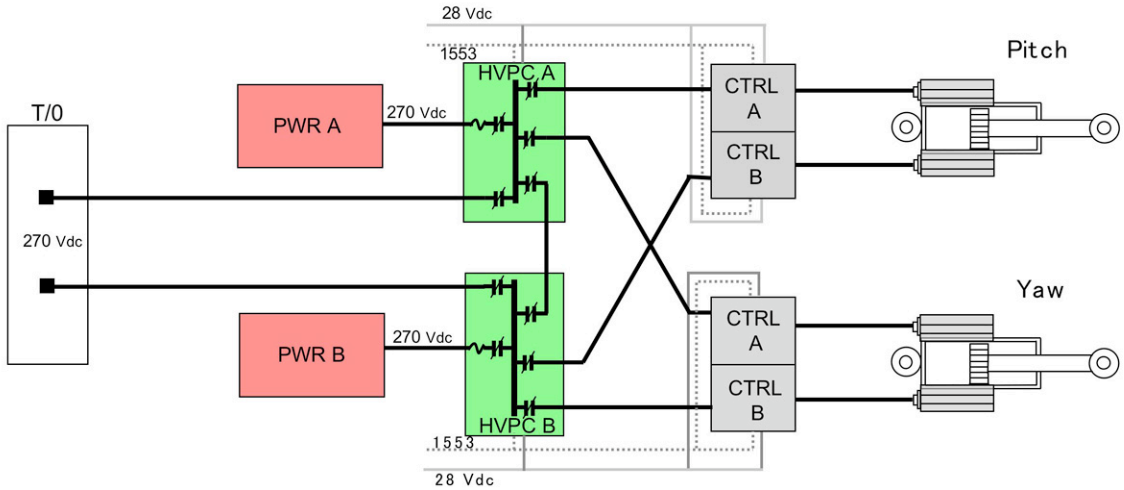

Figure 7.0 Upper Stage TVC Schematic

The Interstage will provide the structural connection between the First Stage and the Upper Stage. The cylinder, constructed of 2195 aluminum-lithium alloy, measures approximately 196 inches in length and 216.5 inches in diameter. The current configuration is based on closed aluminum skin-stringer construction and contains the forward and aft separation systems required to separate the First Stage and the Upper Stages and to separate the Interstage from the First Stage. It will house the First Stage roll RCS systems as well as the Booster Separation Motors (BSM). The Interstage will also contain the Separation system plane between the Core Stage Aft Skirt and the Interstage.

The BSMs will provide the force to translate the First Stage away from the Upper Stage at separation. The BSM design, currently used for Shuttle and baselined for CLV separation, has a diameter of 12.8 inches and a length of 31.0 inches. Each BSM weighs approximately 167 pounds and produce an average thrust of approximately 18,500 pounds, and the average total impulse is 15,000 pound-seconds (lb-sec).

The Upper Stage will provide the RCS subsystems for the First Stage and the Upper Stage of the CLV. The current conceptual configurations are illustrated in Figure 8.0.
The First Stage RCS subsystem, a modular, pressure-regulated hypergolic bipropellant (monomethylhydrazine (MMH) and nitrogen tetroxide (NTO)) system, will provide roll attitude control capability for the active mission operation phase of the First Stage. It will consist of 2 RCS modules, each containing 4 800-lbf thrusters, located 180 degrees apart on the Interstage. The Upper Stage RCS subsystem, also a modular, pressure regulated hypergolic bipropellant (monomethylhydrazine (MMH) and nitrogen tetroxide (NTO)) system, will provide 3 degree-of-freedom attitude control capability for the active mission phase of the Upper Stage when the Upper Stage Engine (USE) is not firing, and will provide roll control capability while the USE is firing. The Upper Stage RCS will consist of 2 RCS modules, each containing 6 100-lbf thrusters, located 180 degrees apart on the Upper Stage thrust structure assembly aft skirt.

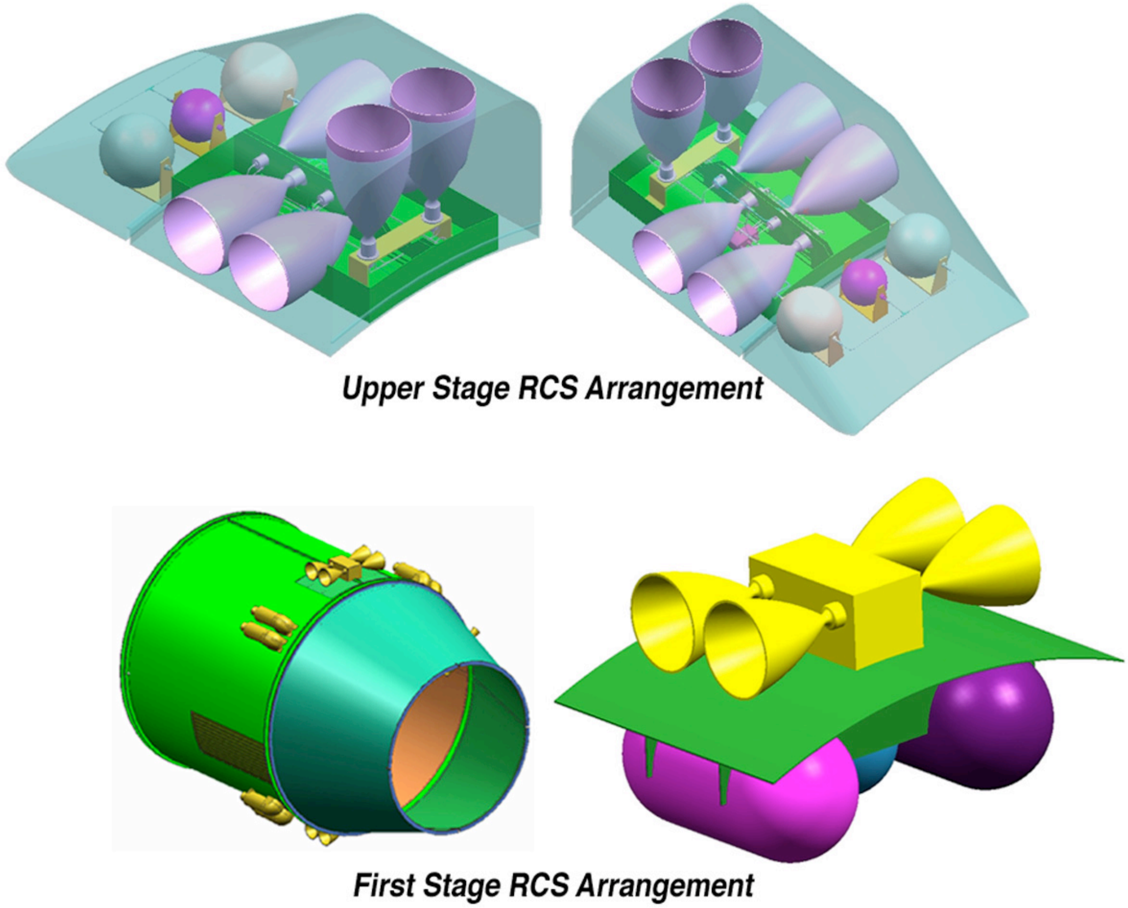

Figure 8.0 Upper Stage / First Stage RCS Concepts

The Instrument Unit (IU) will house the majority of the CLV avionics and will serve as the load-bearing structural interface between the Core Stage and the CEV adapter providing the mechanical and electrical interfaces between the CLV and the CEV. The IU concept as shown in Figure 9.0, will be a 216.5-inch diameter cylinder measuring approximately 60 inches in length, and will be fabricated from 2195 aluminum-lithium alloy. The Avionics, housed in the Instrument Unit, performs the Vehicle Management (VM) and Guidance, Navigation and Control (GN&C) functions. VM includes both the pre-flight stage and vehicle checkout, and the flight system sequencing, health, and management operations. In addition to housing the Upper Stage avionics, the IU will also will house the hazardous gas detection systems and will provide access to the avionics systems for maintenance. Consolidation and packaging the Upper Stage Avionics into this single structure supports production assembly, electrical integration, and avionics system checkout. However, not all of the Avionics will be contained within the Instrument Unit. A small set of electronics including the vehicle subsystem instrumentation, TVC electrical power and associated distributors may be located in other areas on the Upper Stage primary structure.

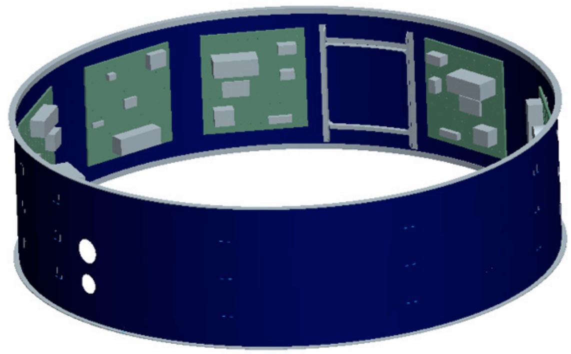

Figure 9.0 Instrument Unit Conceptual Layout

The current Upper Stage Integrated Logistics Support (ILS) strategy is based on a disciplined, unified, and iterative approach to the technical and management activities necessary to integrate supportability considerations into system and equipment design. The end result of the ILS effort is to minimize the support required and costs associated (logistic footprint) for fielding the CLV. The logistics depot for the Upper Stage will be located at MAF. The NASA Design Team (NDT) plans to provide the Upper Stage production contractor a limited inventory of Upper Stage transporters, Electrical GSE, and other support GSE as required for initial manufacture, assembly, checkout and transportation of the integrated Upper Stage(s). NASA expects the provided hardware will require some modification for Upper Stage application. All transportation to and from the manufacturing facility to the launch site will be managed by NASA and will use NASA owned assets.

Upper Stage Development Approach

NASA will lead the Design, Development, Test and Evaluation (DDT&E) for the CLV Upper Stage. The NASA Design Team (NDT) has established the planned DDT&E approach depicted in Figure 10.0.

NASA plans to solicit for an Upper Stage Production (USP) contractor to provide the fabrication, assembly, checkout, and delivery of the completed integrated Upper Stage(s). NASA also plans to solicit for an Upper Stage Avionics Production (AP) contractor to fabricate, assemble and checkout the avionics hardware and systems into the Instrument Unit. It is anticipated that a competitive Upper Stage Production Request for Proposal (RFP) will be released in early calendar year 2007 and a competitive Upper Stage Avionics Production RFP will be released in the spring 2008.

Current plans are for the Upper Stage Avionics hardware and software systems to be designed and developed by the NDT. The NDT will be responsible for performing the DDT&E. The NDT will be responsible for development of the Upper Stage Systems Requirements, development of the CLV external and internal Interface Requirements Documents, development of the Component End Item Specifications, and the definition of the CLV Avionics and Software Architectures.

The NDT will manage the Upper Stage MPS, RCS, and TVC component development programs including the potential for early procurement of long lead critical hardware for advanced development as required to support the NDT design. At this time, the subsystems acquisition approach has not been finalized. However, it is anticipated that competitive RFP(s) for some of the Upper Stage subsystem development programs may be released later this year to support the development and certification of their respective systems.

Descriptions of the key elements included in the development process approach, as illustrated in Figure 10.0, are listed below:

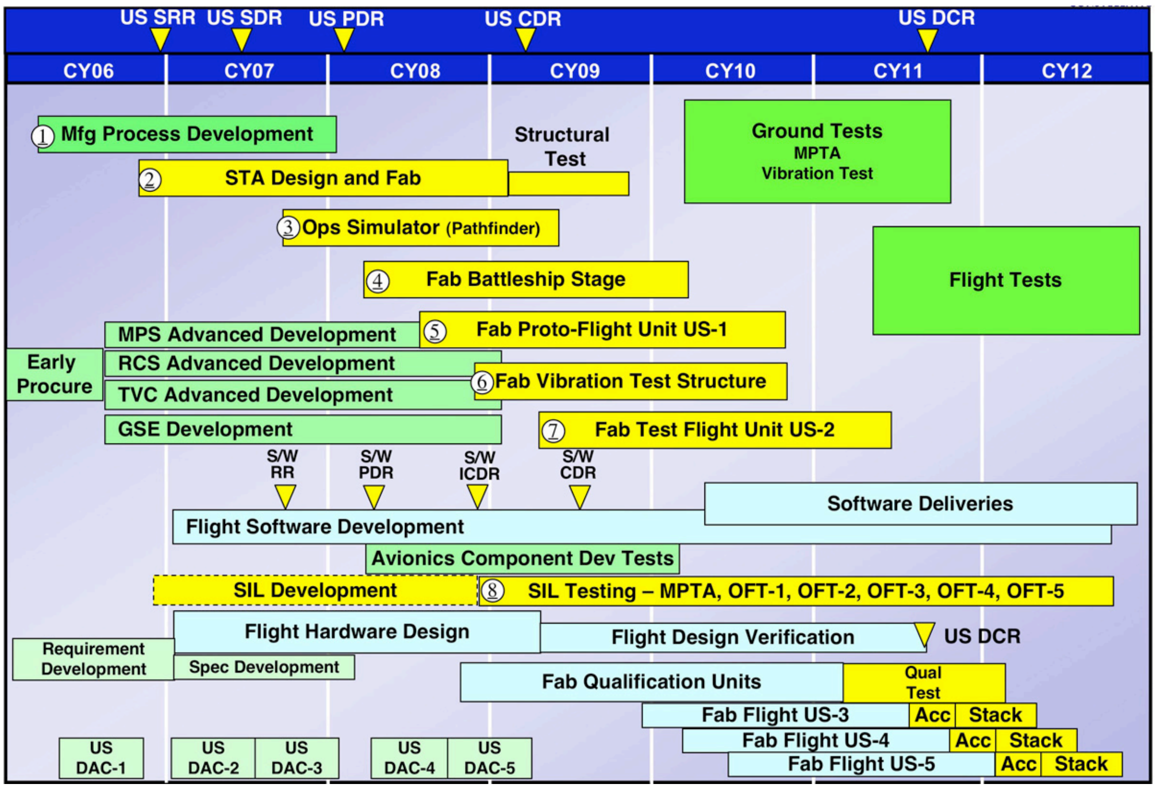

Figure 10.0 Upper Stage Development Approach

1. Process Development Test Articles

Objectives:

- Weld Development and Destructive Test
- Forming Processes Development
- Thermal Protection System Development
- *Configuration:*
  - *Barrel Panels, Domes, Ring Forgings*

2. Structural Test Articles

Objectives:

- Full Scale Manufacturing and Process Development
- Structural Model Validation
- *Configuration:*
  - *Barrel Panels, Domes, Y-rings, Interstage Structure*

3. Upper Stage Simulator (Pathfinder)

Objectives:

- Logistics Demonstrations (lifting, handling, integration)
- *Configuration:*
  - *Low fidelity Structure (OML, Mass and CG, Stiffness)*

4. Battleship Stage MPTA Test

Objectives:

- Propellant Conditioning and Management Model Validation
- Thermal Model Verification
- Pressurization System Performance Validation
- Transient and Main Stage Performance Validation
- Terminal Drain demonstration
- Cryogenic Operations of MPS components
- Restart Testing
- Supportability Demonstration
- Maintainability Demonstration
- *Configuration:*
    - *Low fidelity structure (Match wetted surfaces)*
    - *TPS (Match heat leaks)*
    - *MPS (Match flow parameters and function)*
    - *Ground Avionics (Propulsion systems only)*

5. Proto-Flight Flight Test Article

Objectives:

- Separation Demonstration
- Propellant Management Demonstration
- Engine Start Demonstration
- Flight Validation of all US subsystems models
- Interface Validation
- Supportability Demonstration
- Maintainability Demonstration
- Avionics Demonstration
- *Configuration:*
    - *Higher fidelity Structures and TPS*
    - *Flight like MPS for engine operations*
    - *Flight Avionics*

6. Vibration Structural Test Article

Objectives:

- Structural natural frequency response verification
- Interface validation
- *Configuration:*
    - *Flight structure*
    - *Mass simulators for MPS, Engine, Avionics Boxes*

7. Upper Stage Flight Test Article

Objectives:

- Separation Demonstration
- Supportability Demonstration
- Maintainability Demonstration
- Engine Start, Mainstage, and Shut down
- Propellant Management Demonstration
- Avionics Demonstration
- *Configuration:*
    - *Flight Stage (pre-Qualification)*

8. Integrated Test Facility (Avionics)

- Avionics Development and Certification

9. Upper Stage Qualification Test Articles

- Ground Qualification of all sub-systems

NASA currently plans for Upper Stage primary structure to be fabricated at NASA's Michoud Assembly Facility (MAF). The final assembly of the integrated CLV Upper Stage will require the integration and installation of hardware and/or subsystems at the MAF which will include the Upper Stage Engine, Booster Separation Motors (BSM), and Upper Stage hardware and Upper Stage Avionics hardware and software. The Upper Stage Proto-flight unit will be the first unit fabricated at the MAF and is slated to be the Upper Stage for the first CLV test flight. All transportation to and from the manufacturing facility to the launch site will be managed by NASA and will use NASA-owned assets. The Kennedy Space Center will be responsible for final CLV stack assembly and integration. However, the Upper Stage Office, the USP contractor and the AP contractor will be responsible for providing engineering support as required to support all Upper Stage activities leading up to and following each test flight or human mission.

RFI Requested Response Topics

The specific objective of this RFI is to solicit information within the context of the approach herein that may potentially enhance NASA's planned approach for the CLV Upper Stage development and assist in developing the acquisition strategy. Comments are requested but not limited to any of the following topics.

Government-to-Industry Transition(s)

It is the goal of the CLV Upper Stage office to work closely with the USP contractor selected as soon as possible after contract award to facilitate an efficient integration and transition from a NASA developed design to contractor production. We have patterned our planned approach around the successes of earlier NASA programs such as Apollo and Space Shuttle. It is NASA's desire to have an effective acquisition strategy that allows competitive selection of the USP and AP contractors prior to finalization of the Upper Stage design. Requested responses are as follows:

- Provide any technical, programmatic, contractual challenges, and potential mitigation options that you foresee in transitioning from a NASA design to contractor production.
- Address potential transition of advanced development component contracts into USP contract.
- How can NASA provide data to Industry to reduce risk that will lead to an effective competitive acquisition for the production of Upper Stage and Upper Stage Avionics?
- Cite any specific examples you have experienced with transitions of this nature.
- Key areas of interest include, but are not limited to the following:
    - Transition of NDT developed detailed design drawings and specifications
    - Commonality of design tools / software
    - Configuration control ownership during the transition
    - Subsystem level requirements
    - Issues relating to NASA provided hardware and raw materials such as 2195 Al-Li, existing tooling, and ground support equipment.
    - Continuation of NASA initiated component / subsystem development and qualification tasks
    - Methods to effectively transition contractual arrangements in a seamless manner
    - Design methods to minimize Life Cycle Costs
- Provide any benefits (or the pros and cons) of combining the proposed avionics into the overall Upper Stage Production procurement.

Michoud Assembly Facility (MAF)

The Agency has determined that the Upper Stage manufacture and assembly will be performed at NASA's Michoud Assembly Facility (MAF). Explain the pros and cons that you perceive are introduced into the program by this decision.

Government Furnished Equipment (GFE)

NASA plans to procure the CLV Avionics Hardware and Software systems as well as the Upper Stage Engine outside of this planned USP contractor acquisition. Additionally some of the Upper Stage systems may require early acquisitions of component and associated hardware by NASA to support their respective development and qualification and certification programs. The following information is requested:

- Describe the technical and programmatic challenges foreseen with the integration and assembly of components and / or systems into the final integrated Upper Stage.
- Cite specific examples from your experience with this approach on similar large-scale complex space systems and any lessons learned.

NASA Furnished Raw Materials

The Agency has elected to use residual 2195 Al-Li material from the Space Shuttle External Tank (ET) for the primary structures for the Upper Stage. The material exists in various forms including thick and thin rolled plates. NASA will utilize material from this inventory to develop processes, procedures, tooling and techniques necessary to build the Structural Test Article(s) and the Upper Stage Battleship Main Propulsion Test Article (MPTA). Additional material may be available for fabricating the qualification and development flight articles up through initial series of human flights. The following information is requested:

- Describe how the use of this material could impact your manufacturing and certification processes.
- Any alternative approaches that you wish to suggest. Any alternative approach, including acquisition methods beyond the initial Government Furnished Material, suggested must be capable of maintaining the planned delivery schedule as shown in Figure10.0.
- NASA is interested in the industrial base capable of producing 2195 Al-Li material for subsequent requirements. Please provide information on your company's capabilities if you are interested in potentially producing 2195 Al-Li material.

Contract Type / Incentive Arrangements

NASA is interested in Industry inputs regarding contract type and incentive arrangements that properly balance risk and reward excellent performance. Traditionally the type of effort envisioned would include some form of an award fee or an incentive fee arrangement. NASA is interested in your input on moving towards a Fixed Price contract arrangement that will allow Industry to obtain a higher return on investment for achieving cost savings. We request any input regarding incentive arrangements to include previous experiences that worked well plus any non-traditional ideas on contract types and incentives.

Commercialization

NASA does not wish to preclude the potential commercial use of Upper Stage vehicle or component designs. We are interested in industry input on approaches that NASA should take in the development or acquisition process to avoid creating barriers to commercialization.

Small Business Participation

NASA expects the resultant solicitation will contain significant goals in all socio-economic categories. We solicit your suggestions on how to effectively implement a strong and successful Small and Small Disadvantaged Business Subcontracting Program. You should also note that the MSFC Small Business Office intends to participate in the planned MAF Open House.

Response Instructions

The information obtained will be used by NASA for planning and acquisition strategy development. NASA will use the information obtained as a result of this RFI on a non-attribution basis. Providing data/information that is limited or restricted for use by NASA for that purpose would be of very little value and such restricted/limited data/information is not solicited. No information or questions received will be posted to any website or public access location. NASA does not plan to respond to the individual responses, but will provide an update to the Upper Stage development and acquisition plans at the upcoming Michoud Assembly Facility (MAF) Open House.

This RFI is being used to obtain information for planning purposes only and the Government does not presently intend to award a contract at this time. As stipulated in FAR 15.201(e), responses to this notice are not considered offers and cannot be accepted by the Government to form a binding contract. This RFI is subject to FAR 52.215-3.

All responses should be provided in MS Word document format via electronic media. Font should be Times New Roman, size 12. Responses should not exceed 30 pages. Please submit responses no later than April 10, 2006, to NASA/MSFC Procurement Office, Attn: PS40/Earl Pendley, Contracting Officer, Marshall Space Flight Center, AL 35812. Additional questions should be provided to Earl Pendley via e-mail: George.E.Pendley@nasa.gov.

Points of Contact

Contracting Officer
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Jerry.R.Cook@nasa.gov

MAF Open House Information

The MAF Open House, jointly hosted by the State of Louisiana and NASA, is currently planned begin on the evening of April 18 and will conclude on April 19, 2006. All parties interested in attending this event must RSVP to the email address listed below no later than COB, Friday March 24, 2006. Please provide the following information in your emailed RSVP.

- Name
- Position / Title
- Company
- Contact Information
  - Address
  - Phone Number
  - Email Address

RSVP to: protocol@msfc.nasa.gov.