Heavy Lift Mobility Platform

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Background

The USAF Air Mobility command major strategic transports, the C-17 and the C-5M, are both maturing platforms. The C-5M variant is a re-engined development using a limited number (52) of earlier airframes. Although this mid-life extension of this small sub-fleet will take these airframes into 2040s, they will need to be replaced, and the design and development will need to well precede their end of life so as to avoid a capability gap in service. The USAF Expeditionary role is to provide Rapid Global Mobility to quickly deploy and sustain forces anywhere in the world. This includes airlifting armor, artillery, personnel and support equipment, using it's full range of assets. To meet global requirements, the large transport requirements of the future will need both capacity (for rapid build up of significant assets), and/or range (meaningful capacity for Pacific oriented operations).

Lockheed C-5 Galaxy https://en.wikipedia.org/wiki/Lockheed_C-5_Galaxy

A Heavy-Lift Aircraft (HLA) for the purpose of this RFP is an air vehicle which is capable of delivering, at a cruise speed of Mach .80, a 430,000 lbs payload over an unrefueled range of no less than 2,500 nm, and a 295,000 lb payload to 5000 nm. This aircraft is intended to deliver up to three M-1 Abrams Main Battle Tanks (MBTs) simultaneously (one more than the C-5M) or two M-1 Abrams (same as C-5M), but at ranges more than double what the C-5 can achieve. As historical practice has suggested that flight of an expensive C-5 class asset is rarely risked to be taken directly into the forward threat zones of a conflict, likewise, the HLA will not be compromised for unimproved runway operations. Longer, paved runway capability will be presumed. However, self-sufficiency, in terms of loading and unloading at it's forward deployment will be required. Minimal ground equipment should be required, consistent with current C-5 ground operations, with a low main deck ground clearance and ability to 'drive on and off' as appropriate. The footprint of the overall vehicle shall fit within large ICAO class F airports (limited span of 80 meters when parked)

The HLA as specified offers a significant technical challenge. Aside from the vehicle capability challenges, affordability will be a key consideration. As such, like the C-17 (whose engines were derived from the Boeing 757's P&W 2040 engine family), the HLA will use existing engines in military or commercial transport service. Expected production should be assumed to be 160 units for USAF, and US military allies, plus 20 units for niche level of commercial market sales leveraging it's unique outsized cargo capability.

Requirements (M) = Mandatory Requirement (T) = Tradable requirement

General Requirements

- Design a manned Heavy Lift Aircraft (HLA), including an engine data package with an Entry Into Service (EIS) of 2033
- The HLA configuration is expected to be fixed wing. (M)
- The HLA must be capable of transporting a 430,000 lb payload. The payload type will consist of heavy articles/ 'outsized cargo' including tanks, artillery and helicopters delivered in fulfillment of strategic airlift requirements. The aircraft must also exhibit the ability to deliver tactical payloads including 463L pallets, fully-equipped troops and paratroopers. The aircraft must incorporate provisions to transport no less than: (M)
    a. Three (3) M1A2 Abrams Main Battle Tanks at 71.2 tons each (as specified in Appendix A); or
    b. Forty-eight (48) 463L pallets (a standard air mobility pallet 88 inches wide and 108 inches long); or
    c. One hundred (100) passengers or fully equipped troops/paratroops on a separate deck or compartment from the main cargo bay(s); and three hundred-thirty (330) troops on the main cargo deck bay(s).
- The HLA must be powered by airbreathing powerplant (s) currently in service or anticipated to enter service within the next 5 years. The powerplant(s) may be of U.S. domestic or foreign/international origin. (M)
- The HLA must be a manned aircraft capable of sustaining multiple crews for the purpose of long duration flights in excess of 5,000 nm.
    - Minimum crew size is four, consisting of pilot, copilot and two loadmasters, with provisions carriage of a back-up relief crew of 4 more. (M)
    - Zero-Zero crew escape systems may be provided for crew members, but are not required. (M)
    - Cockpit design must be focused upon crew comfort over long duration flights and must provide optimum visibility. (M)
    - All controls and instruments must be arranged for reduced crew workload. The crew cabin must be pressurized to throughout the flight envelope and aircraft life support systems must have adequate emergency backup. (M)
    - Crewmembers and associated personal affects weigh 300 lbs. (M)

Aircraft Performance and Design Requirements

- <u>PERFORMANCE:</u>
    - The HLA must exhibit an unrefueled range of no less than 2,500 nm (plus reserves) on internal fuel, at a long range cruise airspeed of no less than Mach .80, for the maximum payload weight condition. (M)
    - Maximum cruise shall be Mach = .82. (M)
    - The vehicle must also be able to achieve 5,000 nm (plus reserves) at a payload of 295,000 lb. (M)
    - The ferry range (unrefueled) shall be at least 8,000 nm. (M)
    - Initial cruise altitude capability from MTOW (maximum take-off weight) shall be at least 31,000'. (M)
    - Maximum service ceiling (any flight weight) shall be at least 43,000'. (M)
    - The HLA must have provisions for in-flight refueling via USAF flying boom type receptacle. (M)

- <u>OPERATIONS:</u>
    - The HLA must be capable of operating from existing airports (ICAO code F, or code E, with operational constraints on span limitation while maneuvering on ground) utilizing existing airlift aircraft logistical support structure. (M)
    - The HLA must be able to operate from a field of 9,000' x 150' on an ISA + 15 degrees Celsius day at Sea Level. (M)
    - Landing gear must be designed to permit operations from runways and taxiways of typical of civilian as well as appropriate military airfields. The ACN (aircraft classification number of ACN/PCN method) at MTW (Maximum Taxi Weight) shall be equal to or less than 55 for Flexible pavement with subgrade B (CBR 10, with tire pressures not to exceed 220 psi). (M)
    - The HLA must feature retractable landing gear capable of withstanding 15 ft/s vertical descent rate. (M)
    - HLA takeoff and landing cycles must handle a 30 kt/90 degree cross wind component. (M)
    - The HLA must be capable of operation from deployed locations with self-start capability. The HLA must be of all weather type and incorporate deicing, terrain following and terminal avoidance systems. (M)

- STRUCTURE:
  - HLA design limit load factors are +3 and -1.5 vertical gs with at full zero fuel weight payload and any flight weight up to MTOW. (M)
  - The primary airframe structure may consist of any combination of aircraft grade alloy or composite materials. (T)
  - A safety factor of 1.5 must be used in analysis of ultimate design loads. (M)
  - Structure should be designed for resilience, corrosion resistance and a design service life of no less than 40,000 hours. (M)

- MAINTAINABILITY:
  - The HLA must meet a Maintenance Man Hours per Flight Hour (MMH/FH) no greater than the C-17 (20 MMH/FH) plus 20%. (M)
  - HLA design must permit easy access to all primary systems. Primary systems must be Line Removable Units (LRUs) of self-diagnostic type and must permit timely removal and replacement. (M)
  - A need for unique support equipment must be extremely limited. (M)

- ELECTRIC, HYDRAULIC AND FUEL SYSTEMS:
  - The HLA must employ independent electrical and hydraulic power systems consisting using voltages and pressures that are within current industry demonstrated capabilities (voltages, hydraulic pressures). The optimal combination of systems architectures is left to the proposal team. Alternatively, an 'all electric' design, eliminating the need for traditional hydraulic/electric systems, may be employed provided that a trade study indicating total lifetime cost benefit is provided. (T)
  - HLA fuel systems may consist of integral or self-sealing tanks incorporating integrated fire suppression systems. (M)
  - The aircraft must facilitate ground refueling from a single pressure point refueling receptacle with gravity refueling as secondary backup. (M)
  - Internal fuel must not be stowed within the same structural vessel which serves as the aircraft cargo/passenger bay. (M)
  - Provisions for external fuel are not required.

- AVIONICS, DISPLAYS AND ECM:
  - The HLA must employ Commercial Off-The-Shelf (COTS) avionics including a weather radar, GPS, INS, TACAN, Flight Management and multi-functional displays of color LCD type. (M)
  - The primary flight reference instrument for pilot and copilot is to be a COTS HUD. (M)
  - The HLA must employ military qualified systems including terrain following radar (with corresponding slaved digital flight controls), VHF/UHF radio transceiver, IFF transponder and SATCOM. (M)
  - The HLA must incorporate a complete radar warning and electronic warfare/countermeasures suite capable of self protection against both infra-red and radar guided SAMs and AAMs. (M)

- STABILITY AND CONTROL:
  - The HLA must employ a redundant, digital flight control system incorporating FADEC. The system is to be of closed loop type with an automated flight control system. (M)
  - Static and dynamic stability and handling characteristics must meet MIL-F-8785B requirements. The aircraft may exhibit positive static and dynamic stability, although unstable configurations reliant upon stability augmentation due to static instability along the longitudinal axis are acceptable. (T)

- CARGO HANDLING:
  - The HLA must feature traditional heavy lift aircraft loading and egress systems for cargo handling and all cargo must be contained within contiguous cargo hold. (M)
  - The cargo hold must have a minimum internal height and width of floor at least matching that of the C-5 (13.5' high and internal floor width of 19') with capability to at least carry any typical payload item expected of the C-5. (M)
  - Outsized cargo loading access must be provided for (for example, the C-5 has both aft and nose loading access for outsized cargo such as helicopters, GSE, tanks, etc.), however the HLA minimum requirement is a single access. (M)

- The cargo hold must be accessible by a ramp which will deploy at a maximum ramp down angle of no more than 12 degrees with ramp toes being at a down angle of no more than 16 degrees. (M)
- The cargo hold must incorporate no less than two paratroop doors. (M)

Program Management and Commercial Feasibility Requirements

- FLYAWAY COST AND PRODUCTION RATE: The HLA proposal response must include a per unit flyaway cost in 2022 USD assuming a nominal production run of 90, 180, and 270 aircraft over 15 production years. Total lifecycle and maintainability costs are to be reduced as much as possible to ensure commercial operability of the HLA. This flyaway production cost shall factor in a 10% profit margin per aircraft.
- CERTIFICATION AND QUALIFICATION: The HLA must comply with FAA FAR 25 certification requirements including noise and exhaust gas emission restrictions. The HLA is to be designed to address all applicable MIL-SPECS and must be US DoD qualified. It is anticipated that the HLA will undergo a commercial/contractor managed flight test/qualification program at the AFFTC, Edwards AFB.
- DEVELOPMENT PROGRAM: The HLA must be developed in a reasonable time at an affordable cost. Total development time for the HLA must not exceed 72 months (6 years) from concept definition, to full production. A complete development program summary, with associated development program costs must be provided including an estimation of required simulation and modeling (including wind tunnel, CFD and FEA), prototype development, Demonstration and Validation, Flight Test/Certification and Engineering and Manufacturing Development. A complete approach to program management must be provided including engineering philosophy, risk management and an assessment of lean manufacturing techniques to be employed in the production phase. Competitors are granted the authority to assume that commercial product development practices will be employed throughout the RDT&E process, eliminating the restrictions normally imposed by a U.S. DoD SPO directed program.
- DEVELOPMENT FINANCING: The HLA development program, is assumed to be a cost share with US DoD contribution.
- COMMERCIAL OFF-THE-SHELF: The HLA will be developed and produced taking advantage of Commercial Off-The-Shelf and Military Off-The-Shelf technology and systems where cost effective to do so. In particular, engines already in (or about to be) service shall be used. No new, HLA unique engines are to be presumed. The HLA is to be developed and produced using commercial heavy-lift/wide-body aircraft development practices.
- MARKETING AND COMMERICALIZATION: The HLA will be marketed to US military allies, as well as commercial air carriers. A marketing plan for non USAF customers will be provided.

Proposal and Design Data Requirements

The technical proposal shall present the design of this aircraft clearly and concisely; it shall cover all relevant aspects, features, and disciplines. Pertinent analyses and studies supporting design choices shall be documented.

Full descriptions of the aircraft are expected along with performance capabilities and operational limits. These include, at a minimum:

1. A description of the design missions defined for the proposed concepts for use in calculations of mission performance as per design objectives. This includes the selection of cruise altitude(s) and cruise speeds supported by pertinent trade analyses and discussion.
2. Aircraft performance summaries shall be documented and the aircraft flight envelope shall be shown graphically.
3. Payload range chart(s)
4. A V-n diagram for the aircraft with identification of necessary aircraft velocities and design load factors.
5. Materials selection for main structural groups and general structural design, including layout of primary airframe structure as well as the strength capability of the structure and how that compares to what is required at the ultimate load limits of the aircraft. The maximum dive speed of the aircraft shall be specified.
6. Complete geometric description, including dimensioned drawings, control surfaces sizes and hinge locations, and internal arrangement of the aircraft illustrating sufficient volume for all necessary components and systems.
    a. Scaled three-views (dimensioned) and 3-D model imagery of appropriate quality are expected. The three-view must include at least:
        i. Fully dimensioned front, left, and top views
        ii. Location of aircraft aerodynamic center (from nose)
        iii. Location of average CG location (relative to nose)
        iv. Tail moment arms

b. Diagrams and/or estimates showing that internal volume requirements are met, including as a minimum the internal arrangements of the passenger, cargo and maritime surveillance variants.
    i. Cross-section showing passenger and cargo configuration
    ii. Layout of cargo and size and location of any unique cargo doors
    iii. Fuselage centerline diagram
c. Diagrams showing the location and functions for all aircraft systems.
d. Figure showing the waterline and center of buoyancy at maximum taxi weight for both forward and aft CG conditions.

7. Important aerodynamic characteristics and aerodynamic performance for key mission segments and requirements
8. Aircraft weight statement, aircraft center-of-gravity envelope reflecting payloads and energy weight allocation. Establish a forward and aft center of gravity (CG) limits for safe flight in the normal categories.
    a. Weight assessment summary shall be shown at least at the following level of detail:
        i. Propulsion
        ii. Airframe Structure
            1. Wing
            2. Empennage
            3. Landing Gear
            4. Fuselage
        iii. Control systems
        iv. Payloads
        v. Systems
            1. Instruments and Avionics
            2. Fuel/oil (battery if electric)
            3. Hydraulic/pneumatic/electrical systems (if chosen)
9. Propulsion system description and characterization including performance, dimensions, and weights. The selection of the propulsion system(s), sizing, and airframe integration must be supported by analysis, trade studies, and discussion
10. Summary of basic stability and control characteristics; this should include, but is not limited to, static margin.
11. Summary of cost estimate and a business case analysis. This assessment should identify the cost groups and drivers, assumptions, and design choices aimed at the minimization of production costs.
    a. Estimate the non-recurring development costs of the airplane including engineering, certification, production tooling, facilities, and labor
    b. Estimate the fly away cost for aircraft buys of 90, 180, and 270 units
    c. Estimate of direct operating cost per airplane flight hour
12. Lifecycle emissions analysis, which includes:
    a. Emissions associated with aircraft production
    b. In-service emissions
        i. Analysis should include key greenhouse gases such as Carbon Dioxide and Nitrous Oxide

The proposal response will include trade documentation on the two major aspects of the design development, a) the concept selection trades, and b), the concept development trade studies.

A) The student is to develop and present the alternative concepts considered leading to the down-select of their preferred concept. The methods and rationale used for the down-select shall be presented. At a minimum, a qualitative assessment of strengths and weaknesses of the alternatives shall be given, discussing merits, leading to a justification as to why the preferred concept is the best proposal response. Quantitative justification of why the selected proposal is the best at meeting the proposal measures of merit(s) will strengthen the proposal.
B) In addition, the submittal shall include the major trade studies conducted justifying the optimization, sizing, architectural arrangement, and integration of the specifically selected proposal concept. Quantitative data shall be presented showing why their concept 'works' and is the preferred design compromise that best achieves the RFP

Specific analysis and trade studies of interest sought in proposals include:

1. Mission performance and sizing for the definition of a mission profiles.
2. Overall aircraft concept selection (airframe and propulsion system) vs. design requirements objectives

All concept and technology assumptions must be reasonable and justified for the EIS year.

APPENDIX A

M1A2 Abrams Main Battle Tank (MBT)

General Arrangement, Weight and Dimensions

The M1A2 Abrams Main Battle Tank for the purpose of this RFP has a weight of 69.54 tons. Dimensions of the M1A2 include an overall length of 387 inches (with gun forward), an overall width of 144 inches, and a turret height of 93.5 inches. A General Arrangement Drawing is as provided: