X-33 ADVANCED TECHNOLOGY DEMONSTRATOR

The next generation of U.S. launch vehicles must dramatically lower the cost of space access. Today, many promising space missions and experiments are grounded because of overwhelming launch costs—only the Nation's highest priority payloads are being launched. An all-rocket Single Stage to Orbit (SSTO) fully Reusable Launch Vehicle (RLV) appears to be the best blend of near-term achievable technology and affordability for low-cost routine space access after the turn-of-the-century. Unlike the Space Shuttle, it will not expend stages during its ascent to orbit, simplifying ground and flight operations and processing requirements. The goal of the X-33 advanced technology demonstrator is to mature the technologies essential for an SSTO next-generation reusable launch system capable of reliably serving National space transportation needs at substantially reduced costs.

Primary Objectives. The X-33 is an experimental SSTO rocket proof-of-concept demonstrator. The primary objectives of the X-33 are to (1) mature the technologies required for the next-generation system, (2) demonstrate the capability to achieve low development and operational cost, and rapid launch turnaround times and (3) reduce business and technical risks to encourage significant private investment in the commercial development and operation of the next-generation system. The X-33 will begin flight testing by the end of the decade.

X-33 Requirements. The overarching requirement is that the X-33 system, subsystems, and major components will be designed and tested so as to ensure their traceability (technology and general design similarity) and scaleability (directly scaleable weights, margins, loads, design, fabrication methods, and testing approaches) to a full scale SSTO rocket system.

The X-33 will demonstrate the critical technologies needed for orbital SSTO rockets in realistic operational environments. To the extent practical, the X-33 will be tested in the ascent and

reentry flight environments of a full-scale SSTO rocket. Critical characteristics of SSTO systems, such as the structural/thermal concept, aircraft-like operations and maintenance concepts, flight dynamics, flight loads, ascent and entry environments, mass fraction, fabrication methods, etc., will be incorporated into the X-33 system.

In addition, the X-33 will focus on those operational issues which are critical to the development of reliable low cost reusable space transportation. The X-33 will incorporate more advanced materials with weights and margins equivalent to those required by an SSTO rocket. The X-33 ground support and flight control systems will be designed to accomplish operations and supportability goals which are key to lower cost system operations. The operability and performance demonstrated by the X-33 will provide the necessary data to establish the detailed requirements for a future operational SSTO.

As a minimum, the X-33 will be an autonomous, suborbital, experimental, single-stage rocket flight vehicle.

X-33 Concepts. Three basic classes of X-33 are being investigated. The X-33 will be approximately one-half of the geometric scale of the next generation system.

As depicted in Figure 1, the Lockheed Martin team is pursuing a vertical takeoff, horizontal landing lifting-body configuration. This vehicle relies on its outer-moldline shape to provide aerodynamic lift during reentry and landing in a gliding mode. Another unique aspect of this configuration is the use of a linear aerospike main engine system integrated with the lifting-body shape. This engine was an alternate to the current Space Shuttle Main Engine in the early stages of Space Shuttle development. An aerospike is an altitude compensating nozzle which uses an external expansion surface (i.e., a bell-type nozzle reversed inside-out) combined with changing

ambient air pressure to maintain an optimal expansion ratio. This allows the system to gain greater engine performance compared to conventional bell-type nozzles.

Figure 2 depicts the McDonnell Douglas / Boeing team vertical takeoff, vertical landing configuration. After completing reentry in a nose-down attitude, the vehicle performs a rotation maneuver to a tail-down orientation in preparation for a propulsive landing. This maneuver has been demonstrated in the DC-X program which was conducted by the Ballistic Missile Defense Organization from 1993 to 1995. The DC-X was a quarter-scale (40 ft or 12 m in height) demonstrator of a next generation system which was intended to prove that a cryogenically fueled rocket could be operated more like an aircraft.

Figure 3 depicts the Rockwell team vertical takeoff, horizontal landing winged-body configuration. The Rockwell concept requires a delta-shape wing for aerodynamic lift during reentry and landing. This vehicle reenters and lands in a glide mode similar to that of the Space Shuttle.

All of the concepts require approximately 500 kbf or 2,200 N class of vacuum thrust for main propulsion. This will allow the X-33 to reach a minimum velocity of Mach 15, which is required in order to accurately simulate the aerodynamic and aerothermodynamic loads which will be experienced on the next generation system.

Current Activities. A competitive X-33 concept definition/design activity combined with ongoing technology developments and demonstration is currently underway. This effort, initiated in 1995, will culminate in the downselection of the X-33 concept / industry team in July of 1996. A wide range of technology candidates will be demonstrated to a level of maturity sufficient to reduce the number of alternatives, enabling the design and development of a cost-effective, large-scale technology demonstrator.

Flight Testing. The X-33 will serve as the flight testbed for large-scale elements of critical reusable launch vehicle technologies. The X-33 vehicle will be flight tested, using an incremental envelope expansion process and will demonstrate "aircraft like" operations (minimal ground crew size, short turnaround times, etc.). Testing will start in relatively benign flight environments (e.g., subsonic), moving to hypersonic flight as confidence in the system is built. Flight testing will be accomplished at an appropriate test range. Edwards Air Force Base in Mojave, CA, White Sands Missile Range in Las Cruces, NM and Cape Canaveral Air Force Station in Florida are the primary launch points being evaluated. The X-33 may require up to 1,000 miles or 1,610 km between launch and landing points in order to adequately simulate the next generation system's ascent and reentry profiles. Existing and / or temporary facilities will be utilized in order to maximize system flexibility while minimizing costs.

Key Technology Demonstrations. The following represent the critical technologies that the X-33 must demonstrate in order to adequately reduce the technical risk to development of a next generation system. These will be demonstrated in a combination of X-33 flight testing to verify system performance and operability in combined environments as well as parallel ground testing to more rigorously understand individual system responses to extended life cycle and failure mode tests:

Vehicle Structural /Thermal Technologies. Vehicle structural / thermal technologies encompass reusable cryogenic tank systems, graphite-composite structures, and Thermal Protection Systems (TPS). The efforts focus on the operability and integration of the load-carrying airframe structure, cryogenic insulation (as required), reentry thermal protection material, and associated health management for the next-generation system.

The reusable rocket must return from orbit with its cryogenic propellant tanks, presenting complex thermal-structural challenges. Issues associated with life-cycle effects on the integrated tank system—tank wall, cryogenic insulation, and TPS—must be addressed. Aluminum-lithium (alloys) and graphite-composite tank materials are being considered. To significantly reduce structural mass and alleviate fatigue and corrosion concerns, nonpressurized airframe structures will be constructed of graphite composite, drawing on current aircraft and rocket designs. These include both low- and high-temperature composites materials (Cyante Ester, Graphite IM7 / BMI). TPS candidates for acreage areas include both ceramic and metallic concepts. Leading edge, nose cone, and control-surface material candidates include advanced carbon/carbon and ceramic matrix composites.

Propulsion Technologies. Propulsion technology efforts will demonstrate the operational and performance characteristics of candidate engine and main propulsion systems and define and establish a set of derived requirements for an operable propulsion system. Key targets for the next-generation propulsion system are robustness, operability, high thrust-to-weight ratio, and an affordable development program with acceptable risk. Ground-based engine and main propulsion systems demonstrations will provide a testbed for demonstration of operability and performance targets.

Candidate engine systems currently identified for reusable vehicles are based on liquid oxygen / liquid hydrogen engines. Engine concepts being evaluated include a Space Shuttle Main Engine (SSME)-derived engine, a linear aerospike engine and a Russian RD-0120-derived engine (Energia launch vehicle core stage engine). Key technologies for these concepts include oxygen rich compatible materials, modular combustion chamber development, and the use of advanced ceramic matrix composite materials in component designs.

Operations Technologies. Short turnaround times, small ground crews, and airline-type maintenance procedures are critical to achieving dramatic reductions in operations costs. Automated operations technologies to be applied include automated checkout, vehicle health management/monitoring systems, autonomous flight controls and "smart" avionics/guidance navigation. Incorporation of process enhancements such as one-time flight certification, hazardous materials elimination, ground-scheduling systems, and a philosophy of reliability-centered maintenance and minimum operations between flights will contribute to an aircraft-like operations process.

A New Way of Doing Business. The ultimate goal of the X-33 is to mature the technologies to a degree that will allow private sector development and operation of the next generation system. In order to promote this commercial goal, NASA has given industry the lead in the development of the X-33 with government laboratories contributing critical research and development expertise and facilities. Based on the results of the X-33 program, the Nation will be able to make a decision at the end of the decade on the feasibility of a commercially developed and operated space launch system.

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