VENTURESTAR™ - A REVOLUTIONARY SPACE TRANSPORTATION LAUNCH SYSTEM

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Abstract

Lockheed Martin is developing the VentureStar™ Single Stage To Orbit Reusable Launch Vehicle system. The VentureStar™ launch system is a revolutionary approach to dramatically reduce the cost of space access. This paper describes the VentureStar™ launch system, system performance, design approach, operations concept and development plan.

INTRODUCTION

Over the last 10 years, numerous national studies have examined our space launch capability and have concluded our space launch systems are expensive, labor intensive, delay prone, and not competitive. In 1993, the National Aeronautics and Space Administration (NASA) conducted an access to space study (NASA 1994) to identify the best vehicles and transportation architectures to make major reductions in the cost of space transportation. This study concluded that a new, fully reusable, Single Stage to Orbit (SSTO) launch system offered the best approach to achieving a true national need—affordable access to space. Lockheed Martin is developing such a system - VentureStar™, a SSTO Reusable Launch Vehicle (RLV) launch system.

VentureStar™ is a commercially developed, SSTO launch system whose development and operation will dramatically reduce the cost of access to space. Currently, depending on orbit, an expendable launch system costs an average of between $11,000 to $22,000 to launch one kilogram of payload to orbit. Expendable launch systems possess a cost floor dictated by the cost to manufacture a new launch vehicle for each flight. Fully reusable systems, however, have the potential to break through this cost floor by eliminating the need to manufacture the launch vehicle for each flight. During initial service, the reusable VentureStar™ will launch payloads at approximately one half the cost of today's launchers. Initial launch revenues will both pay for recurring costs and pay back the debt incurred to finance the development and fabrication of the launch system. Once financial debt has been paid off, VentureStar™ will be able to offer payload launch at costs on an order of magnitude below today's costs ($1,100 to $2,200/kg.). Follow on second generation reusable launch systems will have the potential to further reduce launch costs to two orders of magnitude below today's cost ($220/kg.)

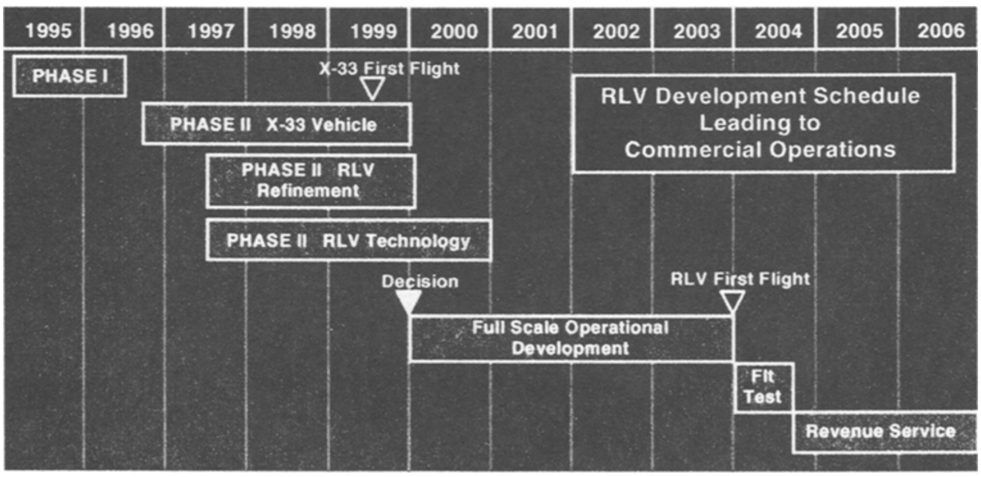

FIGURE 1. VentureStar™ Development Plan.

CP420, *Space Technology and Applications International Forum-1998*
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PROGRAM OVERVIEW

Lockheed Martin has been developing the VentureStar™ system since 1992. Full scale system development is scheduled to begin in December 1999, with first flight scheduled 48 months later in December 2003. The VentureStar™ SSTO RLV development schedule is shown in Figure 1.

Key to VentureStar™ development is the NASA X-33 Advanced Technology Demonstration program. Phase I of the X-33 program was a competition between McDonnell Douglas, Lockheed Martin, and Rockwell International to develop an operational SSTO RLV concept, an X-33 preliminary design, and validate key SSTO technologies. Lockheed Martin was awarded Phase II of the X-33 program on July 1, 1996. Phase II of the X-33 program has three components: Design, fabricate, and fly an X-33 SSTO demonstrator to validate in flight technologies needed to achieve SSTO; Ground test those SSTO technologies which cannot be flown on the X-33, and; Continue design and business development of the operational VentureStar™ SSTO RLV launch system.

The X-33 program is an aggressive program to design, develop, manufacture, and fly the X-33 Advanced Technology Demonstrator three years after go ahead. The X-33 program includes development of the flight vehicle and related propulsion systems, a launch site, and all ground systems required to launch, maintain, and operate the X-33. The X-33 is a one half scale demonstrator of the VentureStar™ design. The design of the X-33 and it's ground elements are directly traceable to the VentureStar™ design. Up to 15 flights are planned for the X-33. Further description of the X-33 design and operations concept can be found in "VentureStar™ Single Stage To Orbit Reusable Launch Vehicle Program Overview (Baumgartner 1997), X-33 Vehicle System Design (Iles 1997), X-33 Technologies (Bunting 1997), and RLV/X-33 Operations Overview (Black/Eshleman 1997).

Figure 2 shows the VentureStar™ Phase II Program Plan. Phase II refinement will validate the VentureStar™ business and technical design. Key criteria which must be met before entry into Phase III (full scale development) have been generated. These criteria fall into four areas:

- Technical - Is the VentureStar™ design technically feasible and practical
- Operations - Can VentureStar™ achieve it's operational goals
- Marketing - Is the launch market sufficient to support a new reusable launch system
- Financial - Is VentureStar's™ development and production cost financeable and can sufficient profit be generated to merit launching full scale development

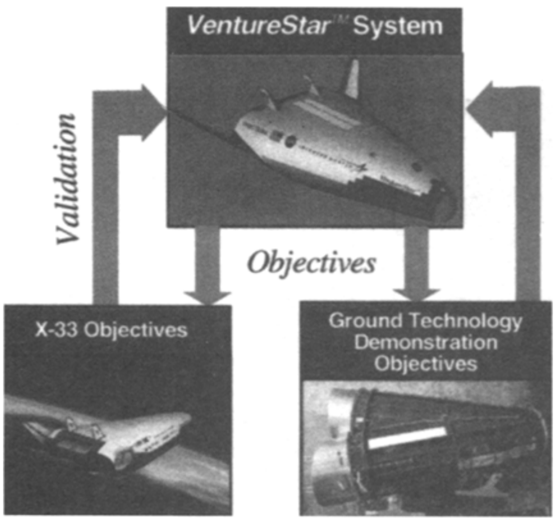

FIGURE 2. Phase II Program Plan.

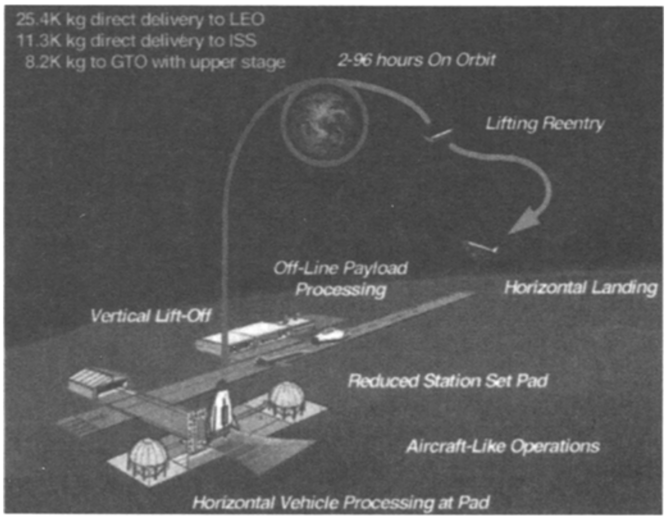

FIGURE 3. VentureStar™ Mission Concept.

VentureStar™ technical, operations, and cost criteria were used to define detail X-33 design and flight test objectives and Phase II ground technology demonstration objectives. Results of and lessons learned from the X-33 and Ground Demonstration Programs will allow initiation of full scale operational system development at the turn of the century.

VENTURESTAR™ MISSION CONCEPT

This Mission Concept selected for our VentureStar™ system is shown in Figure 3. VentureStar™ is a fully reusable, vertical takeoff, horizontal landing, single stage to orbit launch system. Vertical takeoff/horizontal landing were selected by reason of their well known, proven approaches. Horizontal landing facilitates aircraft-like operations and support, horizontal processing and a reduced station ground infrastructure. VentureStar's™ minimal ground infrastructure requirements are:

- LH_2 and LO_2 dewars and propellant loading systems,
- Nitrogen and helium storage and loading systems,
- Built up concrete pad with flame bucket,
- Translating shelter to cover vehicle while being maintained at the launch pad,
- Off line payload processing building,
- Mission control building,
- Standard commercial aircraft runway.

The VentureStar™ has been sized to meet the key mission performance drivers of direct delivery of 11360kg. to International Space Station (459.3km orbit @ 51.6 degree inclination) and deliver the 8180kg post year 2000 growth geosynchronous satellites to geosynchronous transfer orbit (185km x 35786km orbit @ 26.5 degree inclination) with an upper stage. Sized for those performance drivers, the system will be able to place over 25,000kg of payload to low earth orbit (185km orbit @ 28.5 degree inclination due east launch). Typical missions duration are 2 hours for a due east LEO spacecraft delivery mission, 12 hours for a polar LEO spacecraft delivery, and 4 days for a Space Station rendezvous and payload/crew delivery mission.

VENTURESTAR™ VEHICLE DESCRIPTION

Figure 4 presents the VentureStar™ launch vehicle. Key system features include: All composite cryogenic tanks, composite internal structure, LH2/LO2 Linear Aerospike Engine main propulsion, and metallic Thermal Protection System. A complete description of the system trade-offs, technology and design selection of VentureStar™ is given in paper AIAA95-3531 (Baumgartner/Elvin 1995).

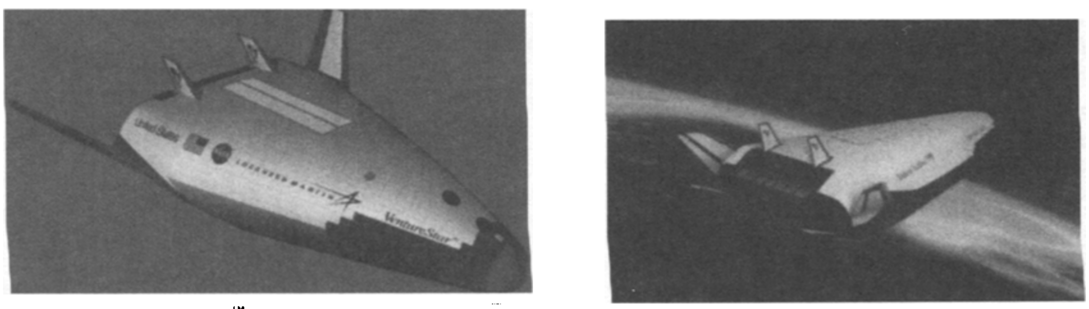

FIGURE 4. VentureStar™ Vehicle.

As shown in Figure 1, the Phase II VentureStar™ RLV system design and technology ground test program began one year after the X-33 flight program. This allows the lessons learned from the X-33 design the be incorporated into RLV system design. X-33 - it's lessons learned, has led to an improved RLV design. This is illustrated in Figure 5. The design of the X-33 has shown which detail design concepts work and which one's need improvement. Some of the lessons learned from the X-33 design activity include:

- Make the cryogenic tanks near outer mold line
- Eliminate parasitic support structure
- Eliminate point loads into composite tanks
- Integrate TPS and tank structure
- Integrate engine and tank structure
- Improve aerodynamic flow and body pitching moments
- Move cg forward

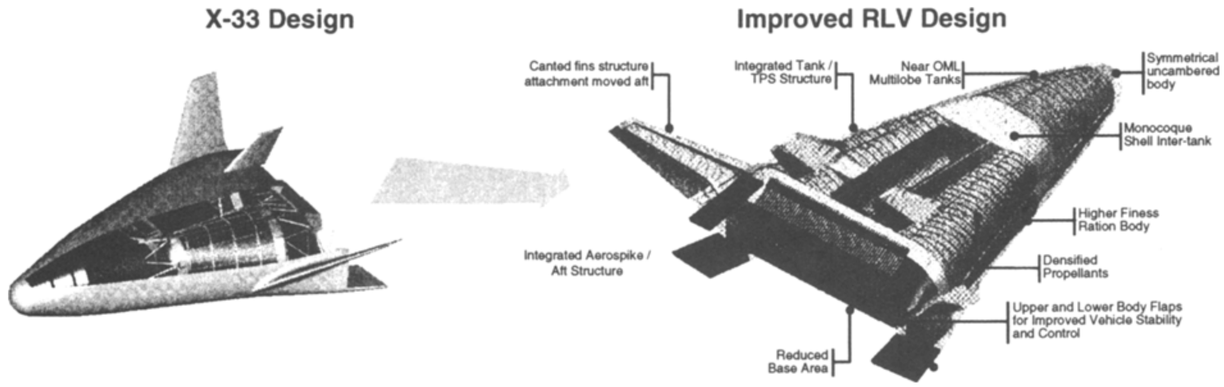

FIGURE 5. X-33 Lessons Learned Have Led To An Improved RLV Design.

The VentureStar™ is powered by seven LH2/LO2 linear aerospike rocket engines. The combination of seven engines, 1.39 vehicle thrust to weight ratio at liftoff, and a 105% emergency engine rating, allowing VentureStar™ to survive the worse case engine loss at liftoff.

The VentureStar™ is covered with a metallic Thermal Protection System (TPS). This TPS is composed of robust, damage resistant, 0.46m x 0.46m PM2000, inconel and titanium panels housing encapsulated thermal insulation. VentureStar™'s nose cap and fin surface edges are oxidation resistant carbon-carbon. The fins are metallic hot structure while the lower body flaps are protected by carbon-carbon. The combination of robust design, cool reentry temperatures afforded by the lifting body design and encapsulating the thermal insulation, eliminates costly repair, replacement and waterproofing operations of the first generation ceramic TPS covering the Space Shuttle.

Internally, the VentureStar™ is essentially a flying fuel tank with the tanks arranged in a lifting body shape. All of the internal structure is composite:

- Graphite composite multilobe LO_2 tank (forward),
- Graphite/epoxy quad lobe LH_2 tanks (aft),
- Graphite/epoxy auxiliary LO_2 and LH_2 tanks beneath payload bay,
- Graphite/BMI monocoque intertank structure,

- Engines are attached to LH2 tank aft domes by close fitting Graphite/BMI monocoque thrust structure,
- Graphite / BMI removable encapsulated payload bay .

All power systems of the VentureStar™ (main engines, on orbit fuel cells, turboalternator for aero surface power, RCS) are fueled by , non toxic, common propellant - H2/O2. VentureStar™ is an all electric vehicle powered by 28V/270V DC power. Aerodynamic and propulsion actuation is by electrical mechanical actuators.

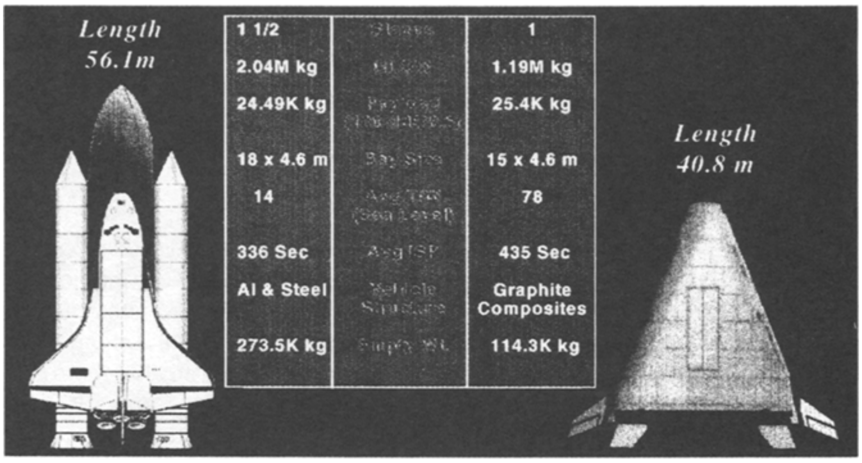

FIGURE 6. Launch System Comparison.

A comparison of VentureStar™ with the space shuttle system is shown in Figure 6. Advancement in technology - replacing steel and aluminum with composite design, replacing LH2/LO2 bell engines and solid rocket motors propulsion with 100% LH2/LO2 linear aerospike propulsion, adopting a single stage architecture based on a lifting body allow VentureStar™ to achieve similar mission performance as the space shuttle at approximately half the GLOW and 40% of the empty weight.

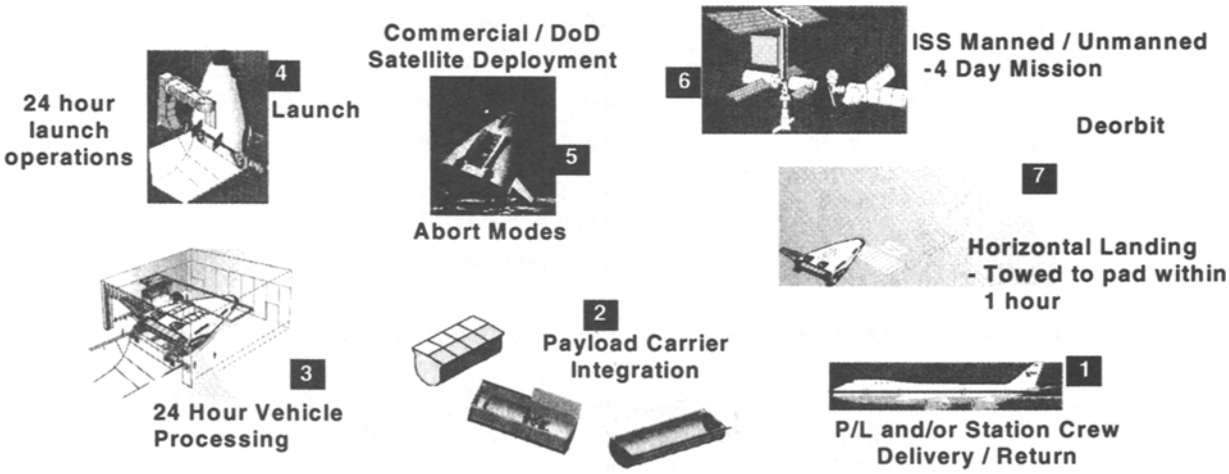

FIGURE 7. Runway to Pad to Orbit to Runway Operations.

OPERATIONS CONCEPT

VentureStar™ incorporates a Runway to Pad to Orbit to Runway operations concept. This is illustrated in Figure 7. Typical missions begin with payload or station crew delivery to the launch site. Payloads are integrated into an encapsulate payload mission module off line in parallel to vehicle processing. After a payload has been processed, the mission module is installed into the flight vehicle during it's 24 hour processing cycle. Mission module installation proceeds rapidly through the use of standard module to flight vehicle interfaces. Once vehicle processing is complete, the maintenance hanger is rolled back exposing the flight vehicle. The flight vehicle is rotated to vertical, propellant's loaded, crew (if any) boarded, and launched. Once launched, the flight vehicle flies to orbit. In the event of engine or multiple equipment failure, the vehicle will either abort to orbit, abort to the original launch site after a once around, or abort to a prepared landing site.

Three classes of missions are envisioned - delivery of spacecraft to low earth orbit, autonomous delivery of cargo to space station, and delivery of crew to space station. For the spacecraft delivery missions, the mission modules payload doors are opened once in orbit and spacecraft deployed. Spacecraft are either delivered directly to their final orbit altitude and inclination or deployed with an upper stage for final orbit insertion. Figure 8 shows an upper stage concept for the heavy GTO payloads. This upper stage is a low cost derivative of the Agena 2000 EELV upper stage. It is a modern storable upper stage weighting approximately 15,000 Kg. Wet. With it, VentureStar™ can deliver payloads weighting up to 9,500 Kg to GTO.

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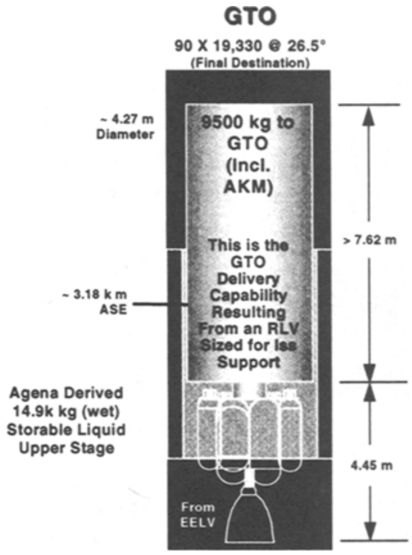

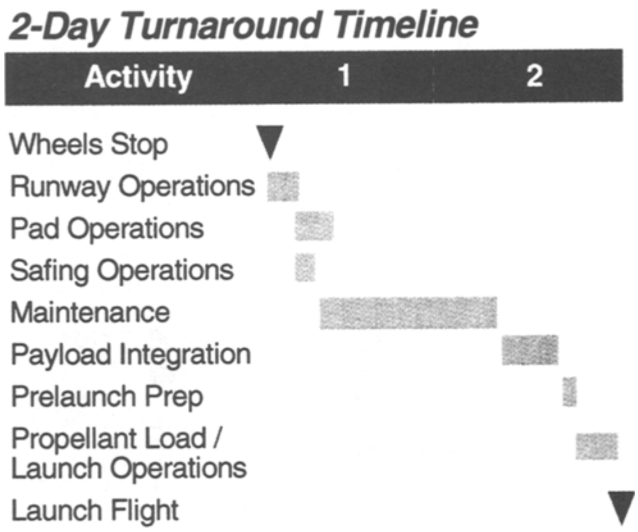

FIGURE 8. VentureStar™ GTO Payload Capability. FIGURE 9. VentureStar™ Ground Operations.

For Space Station missions, VentureStar™ will autonomously rendezvous and dock to station with manual override capability. International Space Station missions will last up to four days. After payload delivery, VentureStar™ performs a deorbit burn, reenters, and lands horizontally at the launch site. The flight vehicle is towed back to the launch pad, hooked up to the pad umbilicals and services, covered with the maintenance hanger, and readied for the next flight.

Typical ground operations time line is shown in Figure 9. VentureStar's™ 2-day turnaround capability will allow revolutionary access to space on demand. This turnaround capability is the result of design for operability features of the VentureStar™ system including:

- Robust vehicle design and operational concept employing repeatable, simplified, and automated processing

- SSTO architecture with horizontal processing incorporating RM&S lessons learned and design for operability
- Circa 2000+ fault detection/fault isolation
- Automated mission planning
- Off line encapsulated payload module integration
- "Lock & Load" payload module to vehicle integration

Key to reducing the ground timeline is the processing of payloads off line into an encapsulated payload mission module. With this concept, multiple missions can be processed outside of the vehicle, breaking the paradigm of integrating payloads directly into the launch vehicle. The mission module allows flexible mission scheduling and manifesting while maintaining standard payload interfaces to the RLV. In lieu of 60 plus days typical of payload integration into the launch vehicles, "lock & load" integration of a pre-processed mission module allows payload/vehicle integration to be performed in hours.

"Manned" Launch System	At First Human Flight		
	Year	(System / Flt. #)	Flt. R.
1st generation ELV			
Redstone - Mercury	1961	69 (1)	0.49
Atlas - Mercury	1962	37 (1)	0.50
Titan - Gemini	1965	36 (1)	0.79
2nd Generation ELV			
Saturn 1B - Apollo	1968	5 (1)	0.75
Saturn V - Apollo	1968	3 (1)	0.50
1st generation RLV			
Shuttle	1981	1 (1)	- -
3rd generation RLV			
VentureStar	2005	18 (18)	- -

FIGURE 10. VentureStar™ - Most Thoroughly Validated Before Human Introduction.

System Safety

VentureStar™ will transport crew to Space Station. This requires an inherently safe system. VentureStar™ will have revolutionary launch safety. It will be the safest launch system ever used to carry humans - the most inherently reliable and the most thoroughly validated before human introduction. The VentureStar™ design incorporates revolutionary features providing it with the most inherent reliability of any launch system devised. VentureStar™ is a single stage system eliminating staging events or requirements for in-flight startup of rocket engines - once main engines are ignited, VentureStar™ has all the propulsion necessary to make orbit. VentureStar™ incorporates all liquid rocket propulsion with health monitoring and safe shutdown capability anytime during mission - eliminates catastrophic or critical one failures of engines. In addition, VentureStar™ has engine out capability off the pad. The combination of post year 2000 embedded sensor s / processing / fault isolation capability with fault tolerant - triplex to quad system redundancy provides unprecedented system reliability.

VentureStar™ will be the most thoroughly validated launch system before human introduction. Figure 10 shows when humans were first flown for previous "Manned" systems, the year, the system and vehicle flight number, and actual system demonstrated reliability at first human flight. For example - for a typical 1st generation expendable - Titan - demonstrated reliability was 0.79 when the first human flight was flown (1965). Although the first manned flight was vehicle number 36, it was the first flight of the actual vehicle that launched. That flight had integration and infant mortality risk commensurate with first flight of a newly manufactured vehicle. VentureStar™, will have flown 18 times when humans are first flown on it. More importantly, the flight vehicle which will first fly humans in

2005, will have already flown 18 times. When humans are first flown on it, it will be a thoroughly validated and checked out vehicle with all integration and infant mortality risks eliminated.

SUMMARY

Lockheed Martin is developing the VentureStar™ next generation reusable Single Stage to Orbit launch system. VentureStar™ will be a revolution in space transportation. The key technology of that system will be validated in the NASA X-33 Phase II program. Flight testing the X-33 technology demonstrator in combination with a RLV technology ground test program and further RLV system definition will validate the RLV technology and system design allowing the full scale development of the world's first SSTO RLV launch system to begin in the year 2000.

Acknowledgment

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Nomenclature

BMI	Bismaleimide
GLOW	Gross Liftoff Weight
LEO	Low Earth Orbit
LO_2	Liquid Oxygen
LH_2	Liquid Hydrogen
NASA	National Aeronautics & Space Administration
RLV	Reusable Launch Vehicle
SSTO	Single Stage to Orbit
TPS	Thermal Protection System
T/W	Thrust-to-Weight