VENTURESTAR™ SINGLE STAGE TO ORBIT REUSABLE LAUNCH VEHICLE PROGRAM OVERVIEW

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Abstract

Lockheed Martin is developing the VentureStar™ Single Stage To Orbit Reusable Launch Vehicle system. The VentureStar™ launch system will drastically reduce the cost to place payloads in orbit. This paper describes the VentureStar™ Single Stage To Orbit Reusable Launch Vehicle Program, system and technology. The technology to achieve VentureStar™ will be demonstrated in the National Aeronautics and Space Administration X-33 Phase II Advanced Technology Demonstration Program. The X-33 program, vehicle, and technology are described herein.

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 a study of space transportation options (1993, NASA) and 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 and launch system, it costs an average of between $11,000 to $22,000 to launch one kilogram of payload to orbit. Illustrated in Figure 1 is the reduction in payload to orbit cost achievable with VentureStar™. Planned entry of the VentureStar™ into revenue service is in year 2004. During initial service in 2004 - 2005, VentureStar™ will launch payloads at approximately one half the cost of toady'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 costs at an order of magnitude far below today's launch costs ($1,100 to $2,200/kg.).

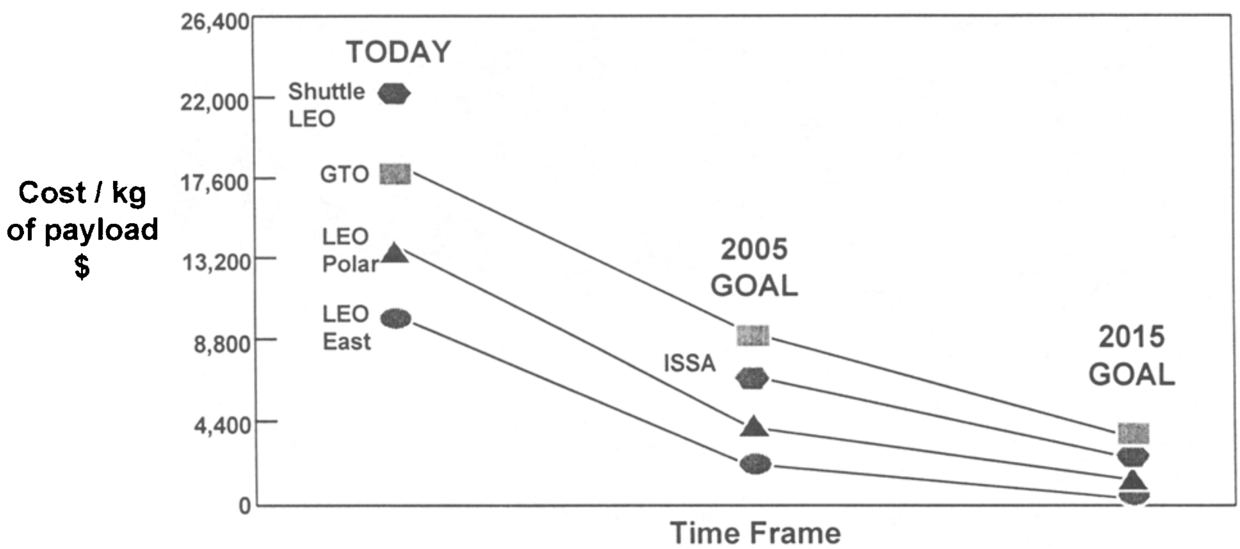

FIGURE 1. Launch Cost Per Pound.

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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 2.

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 RLV concept, a 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 inflight technologies needed to achieve SSTO (described below),
- Ground test those SSTO technologies which cannot be flown on the X-33 (described below), and
- Continue design and business development of the operational VentureStar™ SSTO RLV launch system.

The Phase II portion of the X-33 program has an aggressive 32 month to fly schedule. The RLV technology ground test program begins and ends one year after the X-33 flight program. Successful execution of the X-33 Phase II program will allow initiation of full scale operational system development at the turn of the century. Following the successful system development and flight test program, initial VentureStar™ operational service will begin in 2004.

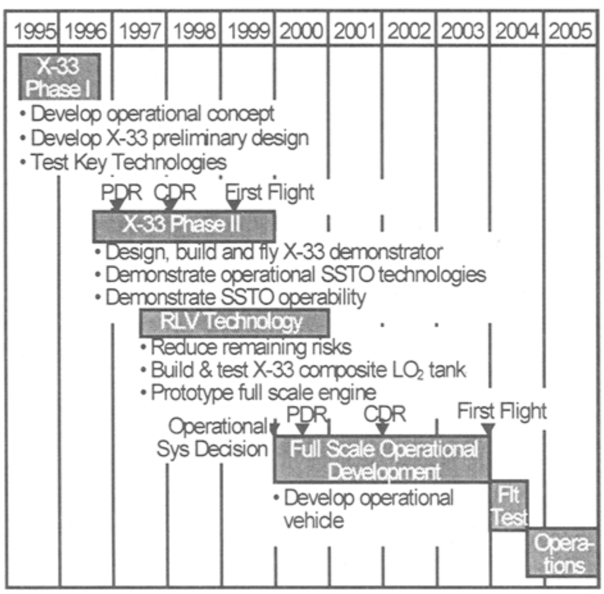


FIGURE 2. X-33 / RLV Program Schedule.

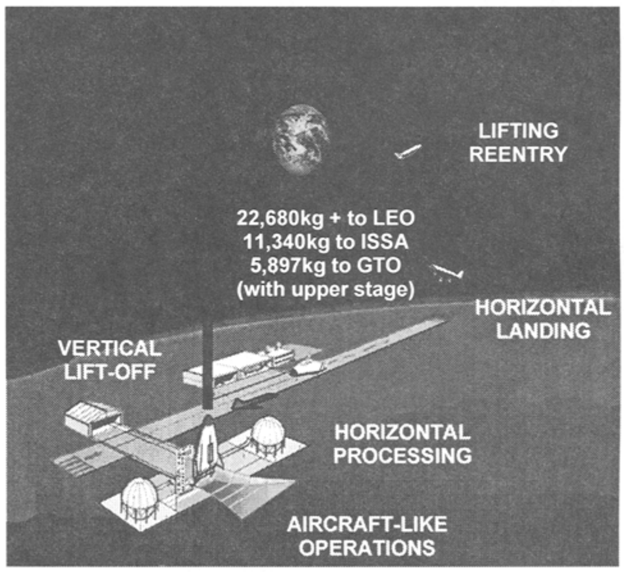


FIGURE 3. SSTO RLV Mission Concept.

VENTURESTAR™ SYSTEM DESCRIPTION

This Mission Concept selected for our VentureStar™ system is shown in Figure 3. Vertical takeoff/horizontal landing were selected by reason of their well known, proven approaches. In addition, horizontal landing allows aircraft-like operations and support, horizontal processing and the ground infrastructure required by the VentureStar™ is minimal. VentureStar™ 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,

• 2.5km runway.

The VentureStar™ has been sized to meet the key mission performance drivers of direct delivery of 11340kg. to International Space Station (444.5km orbit @ 51.6 degree inclination) and deliver the 5897kg post year 2000 growth Geosynchronous satellites to geosynchronous transfer orbit (185km x 35786km orbit @ 26.5 degree inclination). Sized for those performance drivers, the system will be able to place over 22680kg of payload to low earth orbit (185km orbit @ 28.5 degree inclination due east launch).

The VentureStar™ RLV configuration is shown in Figure 4. A complete description of the system trade-offs, technology and design selection of VentureStar™ is given in paper AIAA95-3531 (Baumgartner/Elvin, 1995). The VentureStar™ is a liquid hydrogen/liquid oxygen fueled SSTO lifting body which is powered by seven linear aerospike rocket engines. With the combination of seven engines, 1.39 vehicle thrust to weight ratio at liftoff, and a 105% emergency engine rating, VentureStar™ can survive the loss of two engines at liftoff. Simulations have confirmed the ability to liftoff, abort once around, and land at the launch site after losing an outboard engine on liftoff (worse case).

The VentureStar™ is covered with a metallic panel Thermal Protection System (TPS). This TPS is composed of robust, damage resistant, 0.46m x 0.46m 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.

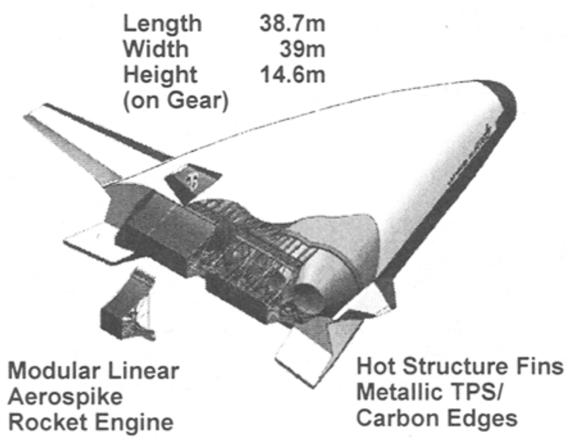


FIGURE 4. VentureStar™ RLV Configuration.

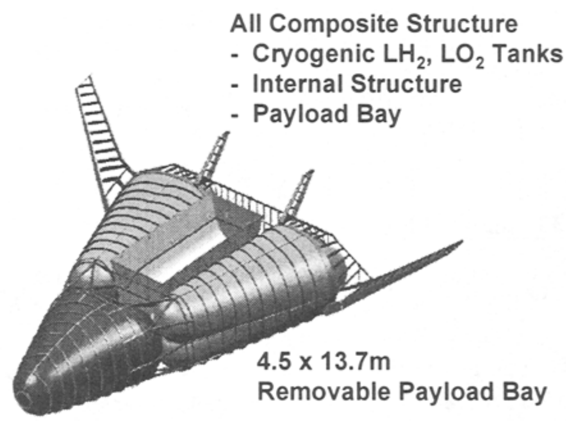


FIGURE 5. VentureStar™ Internal Arrangement.

The VentureStar™ internal arrangement is shown in Figure 5. 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:

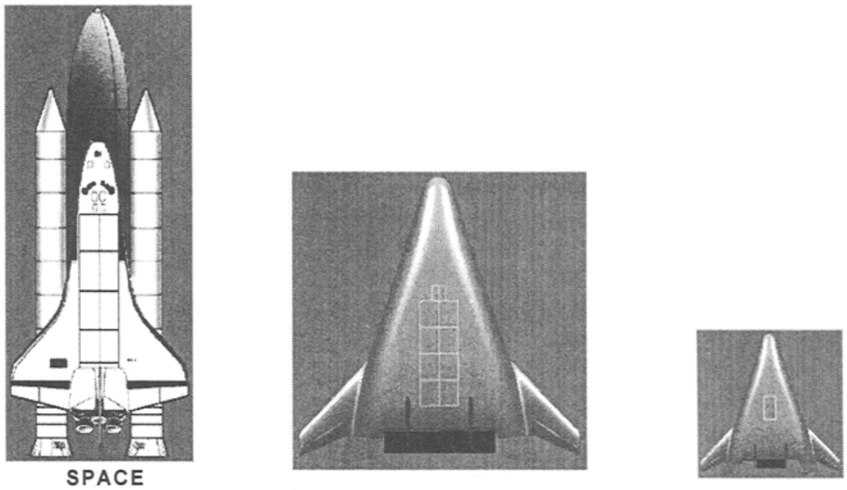
• Unlined graphite composite multilobe LO_2 tank (forward),

• Graphite/epoxy quad lobe LH_2 tanks (aft),

• Graphite/epoxy auxiliary LO_2 and LH_2 tanks beneath payload bay,

- Graphite/BMI truss tube intertank structure,
- Graphite/BMI truss tube thrust structure, and
- Graphite/BMI truss tube payload bay structure.

The payload bay shown is 4.57m x 4.57m x 13.72m and is completely removable to allow off line payload processing. A comparison of the Space Shuttle, VentureStar™ and X-33 launch systems is shown in Figure 6.



SYSTEM	SPACE TRANSPORTATION SYSTEM	VENTURESTAR™	X-33
LENGTH	56.1m	38.7m	20.4m
SPAN	23.8m	39.0m	20.7m
GLOW	2,041,000kg	991,500kg	123,800kg
FUEL	LH_2/LO_2 + SOLID	LH_2/LO_2	LH_2/LO_2
FUEL WEIGHT	1,725,000kg	874,500kg	95,700kg
EMPTY WEIGHT	269,400kg	89,300kg	28,500kg
MAIN PROPULSION	2 SOLIDS + 3 SSME BELLS	7 RS2200 LIN. AEROSPIKES	2 J-2S LIN. AEROSPIKES
LIFT OFF THRUST	28,468kN	13,390kN	1,823kN
MAXIMUM SPEED	ORBITAL	ORBITAL	MACH 15+
PAYLOAD (100 NM/28.5° ORBIT)	23,133kg +	22,680kg +	N/A
PAYLOAD BAY SIZE	4.57m x 18.3m	4.57m x 13.72m	1.52m x 3.05m

FIGURE 6. Launch System Comparison.

X-33 Phase II Plan

Lockheed Martin is currently executing Phase II of the RLV development plan. As shown in Figure 7, our goal in Phase II is to be ready to proceed to Phase III, the full scale development of the operational RLV, at the end of Phase II. Our Phase II program has three components. First program component is the design, fabrication, ground and flight test of the X-33. The X-33 will flight demonstrate the key technologies needed to achieve SSTO. The second program component is technology development and ground test of those items which can not be flown in the X-33. These items include:

- Development and ground test of a full scale prototype of the RLV linear Aerospike engine,
- Development and ground test of an X-33 unlined graphite composite LO_2 tank capable of being dropped into the X-33,
- Cycle testing of an X-33 graphite/epoxy LH_2 tank, and
- Cycle, impact and damage testing of RLV TPS system.

The third program component is continued RLV system optimization and definition.

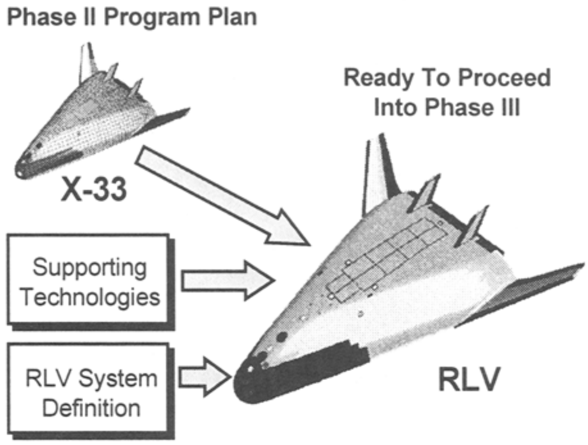


FIGURE 7. Our Goal - Ready to Proceed to Phase III.

SCALE	53% OF RLV
OVERALL LENGTH	20.4m
OVERALL WIDTH	20.7m
HEIGHT (ON GEAR)	7.1m
GLOW	124,000kg
EMPTY WEIGHT	28,400kg

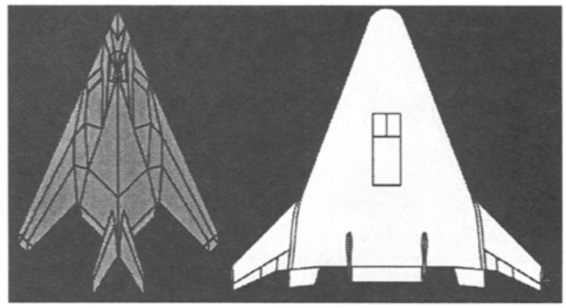


FIGURE 8. X-33 Configuration.

X-33 SYSTEM DESCRIPTION

The X-33 is a 53% scaled replica of the VentureStar™ operational SSTO RLV. As shown in Figure 8, it is similar to the twin engine F-117A in size. Although it is 53% of the operational RLV size, it has roughly 1/8th of the operational RLV's Gross Liftoff Weight. Whereas the operational RLV achieves orbital velocity, the X-33 achieves a maximum velocity of approximately Mach 15 which is sufficient to validate the RLV aerodynamics including real gas effects, validate the RLV aerothermal environment, and validate the RLV metallic TPS design.

An inboard structural profile of the X-33 is shown in Figure 9. With one exception, the X-33 has the same internal arrangement and technology as the operational RLV. In place of the RLV's graphite composite multi lobe LO_2 tank, the X-33 will have a aluminum multi lobe LO_2 tank. As previously mentioned, an X-33 size composite multi lobe LO_2 tank will be developed as part of the ground technology test program. The X-33 has a removable 1.52 x 1.52 x 3.05m composite payload bay, composite internal structure and composite quad lobe LH_2 tanks. Externally, like the RLV, the lower surface of the X-33 will be covered by inconel, and titanium metallic TPS panels. Leading edges and nose cap will be carbon-carbon. For cost reasons, in lieu of the RLV titanium TPS panels, the X-33 will fly with an upper surface composed of graphite composite panels covered with blanket insulation.

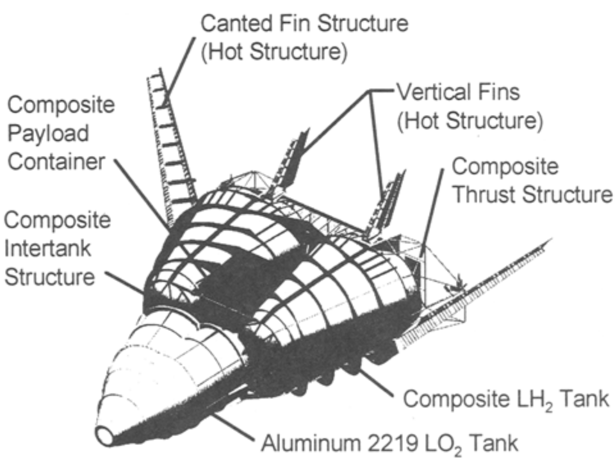
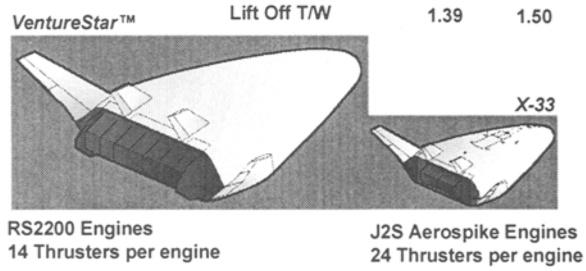


FIGURE 9. X-33 Structural Inboard Profile.

	RLV	X-33
Number of Engines	7	2
Thurst per Engine	1917kN	912kN
Total Thrust	13420kN	1810kN
Lift Off T/W	1.39	1.50



- No recertification between flights
- VHM reduces turnaround inspections
- Improves R&M -- no gimbals, flex lines
- Engine out capability
- Modular components accessible without removal

FIGURE 10. X-33 / RLV Engine Configuration.

The X-33 will be powered by two J-2S powerhead based linear Aerospike engines. Figure 10 compares the X-33 and operational RLV engine configuration. The X-33 engines are roughly one half scale RLV engines. Each is based on a robust gas generator cycle. Both achieve thrust vectoring through thrust modulation rather than gimballing the engines. At full fuel load the X-33 has a liftoff thrust to weight ratio of 1.5. The X-33 has been designed to survive and continue flying with one engine out. At partial fuel loads (90% of the mission) the combination of high liftoff T/W and 120% emergency power rating allows the X-33 to survive an engine out at liftoff.

The X-33 is a virtual replica of the operational VentureStar™ RLV. Flight testing the X-33 will demonstrate the maturity of VentureStar™'s technology. Figure 11 summarizes the SSTO RLV technology that the X-33 will demonstrate.

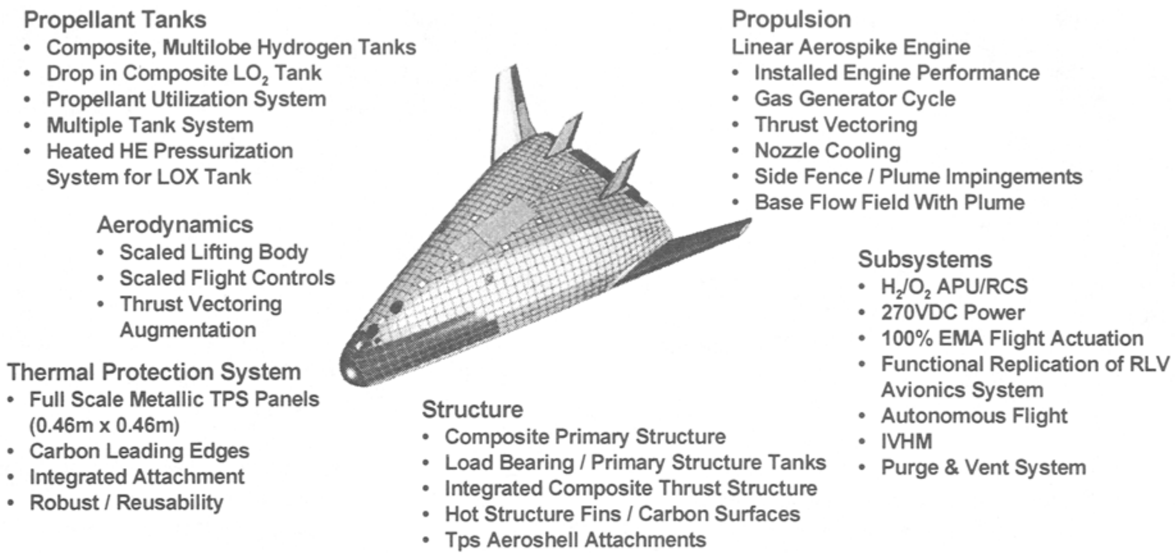


FIGURE 11. Phase II X-33 Flight Test will Demonstrate SSTO RLV Technology.

SUMMARY

Lockheed Martin is developing the VentureStar™ next generation reusable Single Stage to Orbit launch system. The key technology of that system will be validated in the NASA X-33 Phase II program. The X-33 is a scaled replica of the operational SSTO RLV. 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.

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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