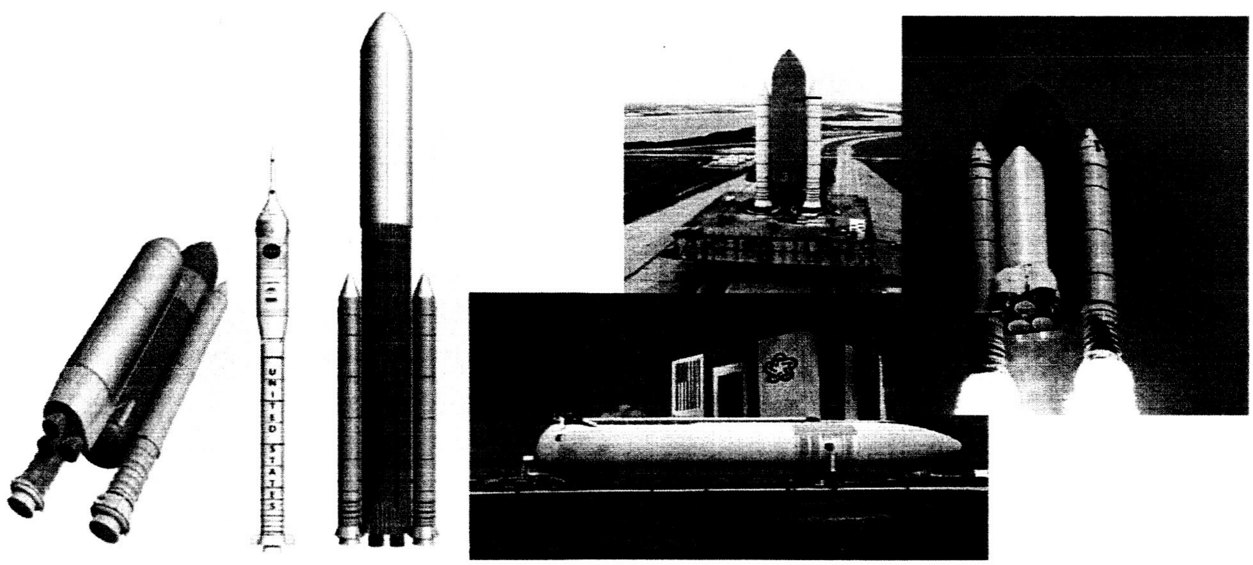
Shuttle-Derived Launch Vehicles' Capabilities: An Overview

William J. Rothschild and Debra A. Bailey (Boeing, NASA Systems), Edward M. Henderson (NASA/JSC), and Chris Crumbly (NASA/MSFC)



For Presentation at the AIAA 1st Exploration Conference

Orlando, Florida, January 30–February 1, 2005

United Space Alliance

ATK THIOKOL PROPULSION

LOCKHEED MARTIN

We never forget who we're working for™

Shuttle-Derived Launch Vehicles' Capabilities: An Overview

William J. Rothschild* and Debra A. Bailey†
The Boeing Company, NASA Systems, Houston, TX 77059

Edward M. Henderson‡
NASA/Johnson Space Center 2, Houston, TX 77058

and

Chris Crumbly§
NASA/Marshall Space Flight Center, Huntsville, AL 35812

Shuttle-Derived Launch Vehicle (SDLV) concepts have been developed by a collaborative team comprising the Johnson Space Center, Marshall Space Flight Center, Kennedy Space Center, ATK-Thiokol, Lockheed Martin Space Systems Company, The Boeing Company, and United Space Alliance. The purpose of this study was to provide timely information on a full spectrum of low-risk, cost-effective options for STS-Derived Launch Vehicle concepts to support the definition of crew and cargo launch requirements for the Space Exploration Vision. Since the SDLV options use high-reliability hardware, existing facilities, and proven processes, they can provide relatively low-risk capabilities to launch extremely large payloads to low Earth orbit. This capability to reliably lift very large, high-dollar-value payloads could reduce mission operational risks by minimizing the number of complex on-orbit operations compared to architectures based on multiple smaller launchers. The SDLV options also offer several logical spiral development paths for larger exploration payloads. All of these development paths make practical and cost-effective use of existing Space Shuttle Program (SSP) hardware, infrastructure, and launch and flight operations systems. By utilizing these existing assets, the SDLV project could support the safe and orderly transition of the current SSP through the planned end of life in 2010. The SDLV concept definition work during 2004 focused on three main configuration alternatives: a side-mount heavy lifter (~77 MT payload), an in-line medium lifter (~22 MT Crew Exploration Vehicle payload), and an in-line heavy lifter (>100 MT payload). This paper provides an overview of the configuration, performance capabilities, reliability estimates, concept of operations, and development plans for each of the various SDLV alternatives. While development, production, and operations costs have been estimated for each of the SDLV configuration alternatives, these proprietary data have not been included in this paper.

* Director, Space Transportation, Boeing NASA Systems, 13100 Space Ctr. Blvd. (MC HS4-20), Houston, TX (AIAA Member)
† Project Engineer, Space Shuttle R&D, Boeing NASA Systems, 13100 Space Ctr. Blvd. (MC HS1-30), Houston, TX (AIAA Member)
‡ Deputy Manager, Strategic Planning Office, Space Shuttle Program, NASA/Johnson Space Center (AIAA Member)
§ Manager, Cargo Launch Vehicle Study, Space Transportation Programs and Projects Office, NASA/MSFC-NP01 (AIAA Member)

I. Introduction

Space Transportation System (STS) assets have been in operation since 1981. They are well understood from technical performance, reliability, operations, and cost aspects. Adapting these proven STS assets to yield new launch systems would take full advantage of demonstrated mature, reliable, human-rated systems to develop impressive performance capabilities with minimum technical, schedule, cost, and programmatic uncertainties. Independent studies done by several industry and NASA teams have shown that such STS-Derived Launch Vehicle (SDLV) concepts offer payload performance over a wide range from 16 to 101 metric tons (MT) to low Earth orbit (LEO). Because of the high technical readiness level (TRL) associated with these STS assets, rapid demonstrations and flight test opportunities could provide early program successes with low schedule and cost risks. Importantly, SDLV development and test activities would enhance the safe "flyout" of the current STS program through continuity of critical skills and manufacturing infrastructure during the transition period. Viable technical and management approaches have been identified that could dramatically reduce the annual recurring costs compared to the current STS system. These operational cost savings are achievable by eliminating the labor- and facility-intensive Shuttle orbiter processes plus the low marginal cost associated with using ongoing STS assets.

II. Objective

The objective of this collaborative industry/NASA study has been to define a broad range of SDLV alternatives that could support NASA's space exploration launch infrastructure needs. We have attempted to assess NASA's current STS assets and evaluate their applicability to future exploration systems' Earth-to-Orbit (ETO) launch needs. Our goal has been to provide timely, useful information on a full range of options, supported by objective facts and data. It was not the intent of these collaborative SDLV studies to recommend an ETO architecture approach or any specific launcher configurations.

III. Options for ETO Transportation Using STS-Derived Launch Vehicles

SDLV offers a variety of configuration approaches to satisfy the crew and the heavy-lift cargo requirements of future human space exploration. The current STS can reliably propel 118 MT to LEO, including the mass of the Space Shuttle orbiter. By conceptually mixing and matching the basic human-rated propulsion system elements of the STS—Space Shuttle Main Engine (SSME), solid rocket boosters (SRBs), and external tank (ET)—one can create a wide range of new launch vehicle concepts, providing payload lift capabilities in the 16 to >100 MT range (Fig. 1). The SDLV work reported in this paper has focused on three main configuration alternatives: a side-mount heavy lifter (~77 MT payload), an in-line medium lifter (~22 MT Crew Exploration Vehicle [CEV] payload), and an in-line heavy lifter (>100 MT payload).

A. Side-Mount Heavy Lifter (43 to 92 MT payloads to LEO)

This configuration is a straight-forward derivative of the current STS configuration, replacing the reusable Shuttle orbiter with an expendable payload carrier. The side-mount heavy lifter SDLV concepts would benefit from the long heritage and extensive learning provided by more than 110 STS launches. The side-mount heavy lifter configuration also enjoys an impressive library of previous design and planning work completed as part of the Shuttle-C project during the 1986–1992 timeframe, making this the most well-understood heavy-lift launch system concept available today. The side-mount heavy lifter concepts require the design and development of a new cylindrical payload carrier that would mount three SSMEs along with the avionics and other subsystems. The standard four-segment SRB configuration would use the current ET propellant volume to yield 77 MT payloads to LEO (Fig. 2). The five-segment SRB configuration could be used with a stretched ET to yield 92 MT payloads to LEO. Both side-mount heavy lifter SDLV configurations could carry either cargo only or a combination of cargo and a CEV (Fig. 3). Preliminary reliability estimates indicate the loss-of-vehicle (LOV) rate would be approximately 1/160 to 1/240, depending on configuration and operational details. In addition to heavy payload mass, these SDLV options offer large payload sizes up to 7.5 meters in diameter and 35 meters long. Taking advantage of the existing or modified STS hardware for the side-mount launcher also allows the use of the current STS infrastructure. Expensive and time-consuming development of rocket engines and boosters would be avoided, enabling the side-mount heavy lifter Design, Development, Test, and Evaluation (DDT&E) program to achieve a first flight test in as little as 48 months from the start of Full-Scale Development (FSD), see Fig. 4. This would enable parallel operations of a side-mount heavy lifter SDLV for a wide range of exploration cargo missions along with a CEV launcher for lunar missions using the same basic launcher and infrastructure. When operated with a CEV, the side-mount heavy

Case		CASE E	CASE C	CASE A	CASE B	CASE D	CASE F	
LV Type	STS	Medium	Min Cost	Shuttle-C	Min Changes	Max Side P/L	Magnum	Saturn V
Engine No. x Type	3 x SSME	1 x RSRM	2 x RS-68	3 x SSME	3 x SSME	3xE-SSME	4xE-SSME	5 x F-1
Upper Stage	OMS/RCS	J-2S	RCS Only	OMS/RCS	RCS Only	RCS Only	J-2S	J-2
MPS Tank	ET	-	ET	ET	ET	Stretch ET	Mod ET	-
Payload Envelope	4.6 m x18.3 m	5 m x 18 m	6.5 m x 25 m	5 m x 25 m	6.5 m x 25 m	6.5 m x 35 m	9 m x 35 m	10 m x Y m
SRB Type	4 Segment	Exp. 4 Seg.	Exp. 4 Seg.	4 Segment	4 Segment	Exp. 5 Seg.	5 Segment	
Net Payload Capability to 220 nmi Circular at 28.5 deg	22 MT 48 klb	22 MT 48 klb	43 MT 94 klb	73 MT 161 klb	77 MT 169 klb	88 MT 194 klb	109 MT 241 klb	134 MT 294 klb
Configuration/ Relative Size								

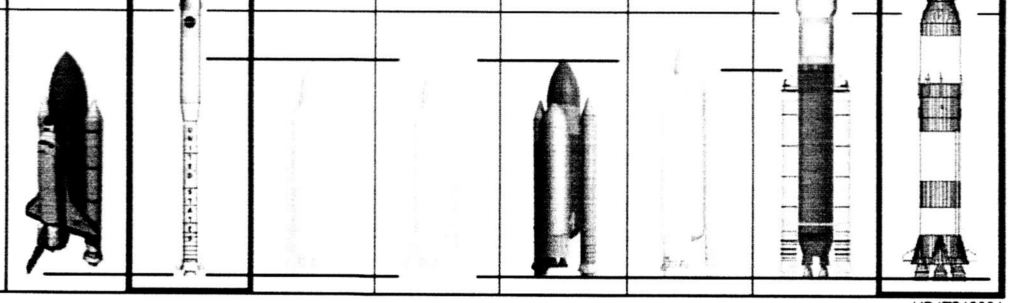
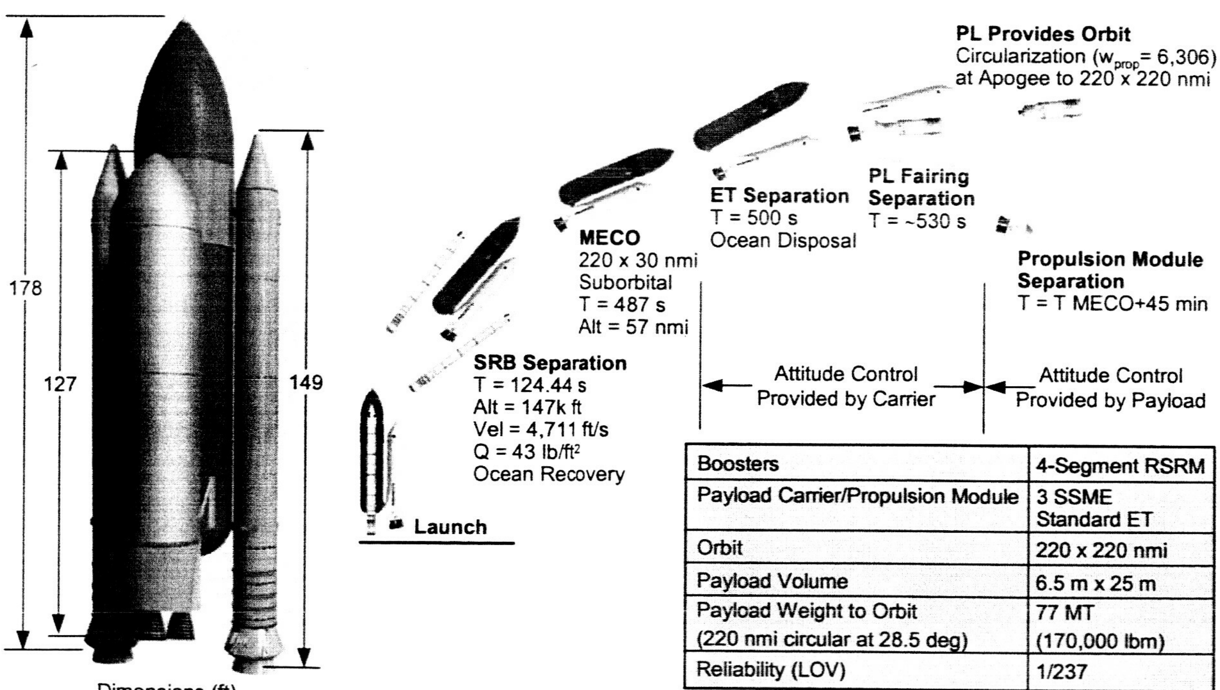


Figure 1. STS-Derived Launch Vehicle (SDLV) options provide a flexible range of payload capabilities to low Earth orbit.



Boosters	4-Segment RSRM
Payload Carrier/Propulsion Module	3 SSME Standard ET
Orbit	220 x 220 nmi
Payload Volume	6.5 m x 25 m
Payload Weight to Orbit (220 nmi circular at 28.5 deg)	77 MT (170,000 lbm)
Reliability (LOV)	1/237

Figure 2. The side-mount heavy-lift SDLV option offers a high-reliability launcher with large payloads for a low loss of mission risk.

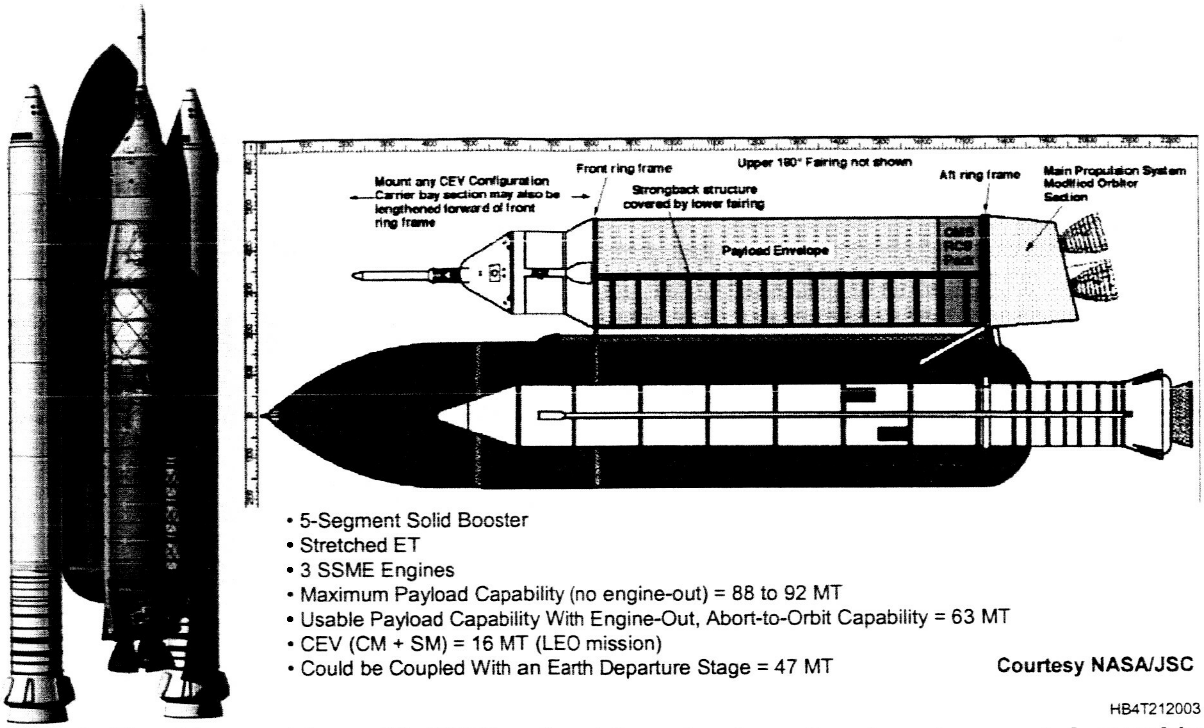


Figure 3. The side-mount heavy-lift SDLV option takes advantage of mature, human-rated propulsion elements as a CEV launcher.

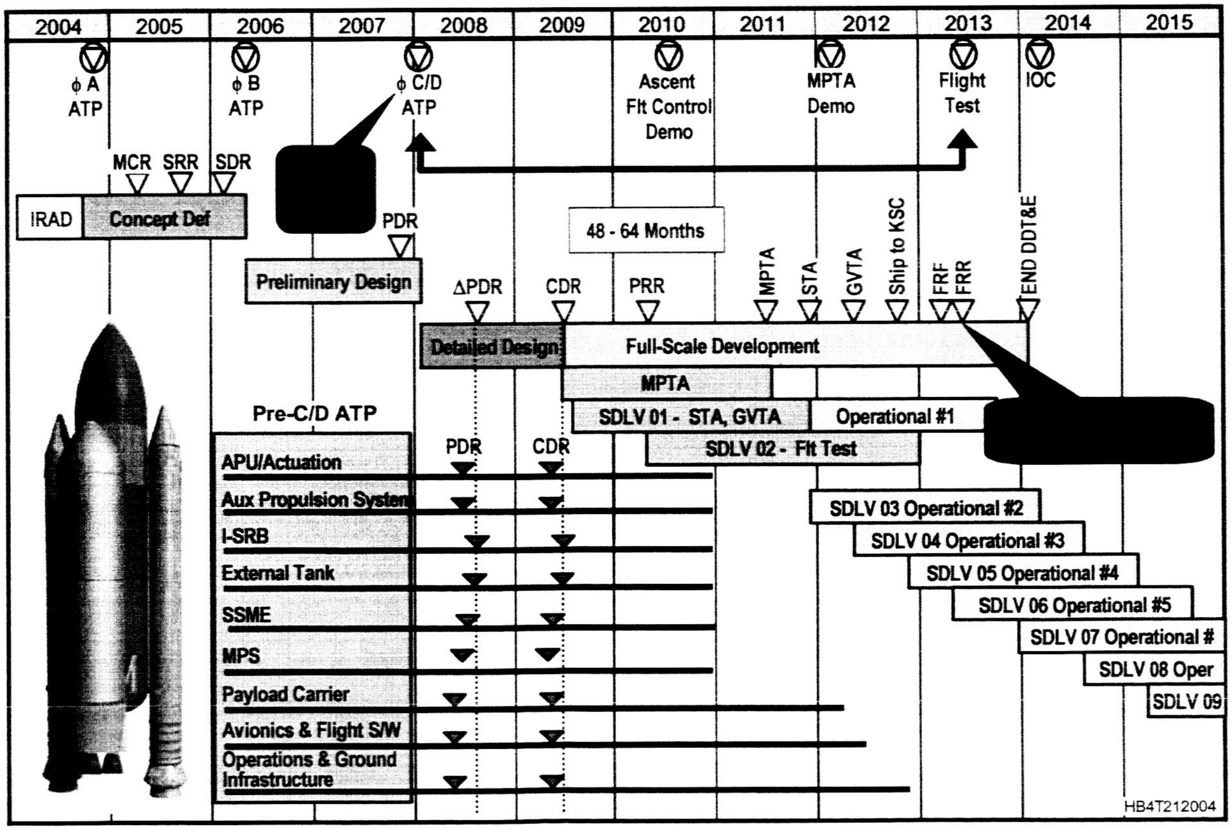
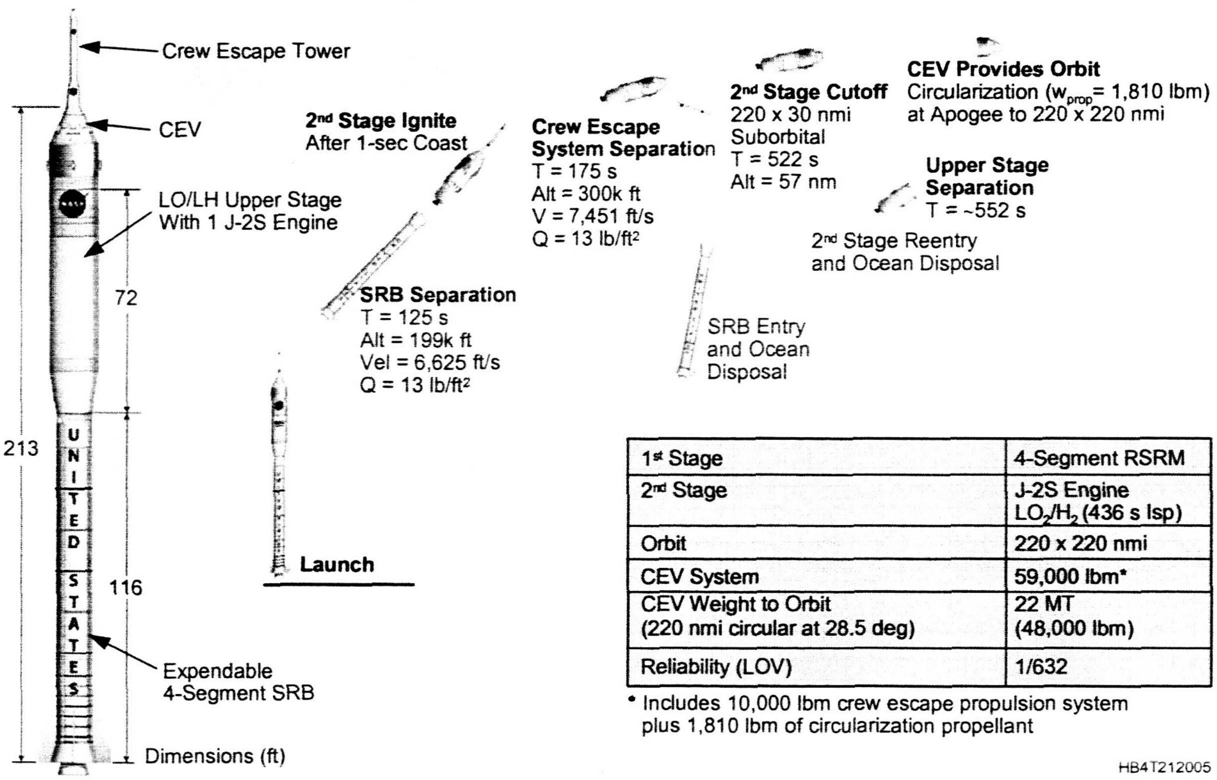


Figure 4. The side-mount heavy-lift SDLV development plan includes 16 months of slack to reduce schedule risks.

lifter SDLV concept could offer an Abort-to-Orbit (ATO) capability, with an engine-out payload penalty of roughly 30 percent. Of the many ETO launcher options available to NASA, the side-mount heavy lifter SDLV configuration is probably the lowest cost and least risk approach for payloads in excess of 45 MT to LEO.

B. In-Line Medium Lifter (16 to 28 MT payloads to LEO)

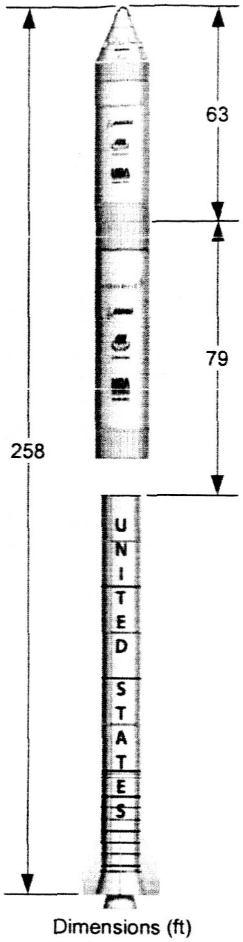
The NASA Exploration Vision requires ETO launch vehicles that have lift capabilities in the 20 MT range to support robotic precursor missions and CEV missions to LEO. In-line medium-lift SDLV concepts could meet both these exploration cargo and crew launch needs (Fig. 5 and 6). These in-line medium-lift SDLV concepts are based on a simple two-stage configuration that uses an existing SRB for the first stage plus a new cryogenic liquid propellant upper stage. The upper stage would use a single J-2S (based on the human-rated Saturn upper stage engine), or a single SSME, or multiple new, high-performance upper stage rocket engines. The relatively high length/diameter ratio of this in-line medium-lift SLDV configuration initially raised concerns about potential control problems. Preliminary stability and control analyses done independently by NASA and industry teams have shown that this configuration should maintain reasonable control margins under worst-case ascent conditions. Using the same basic launch infrastructure, the SDLV medium-lift launch vehicle concept could operate as a CEV launcher in parallel with various SDLV heavy-lift cargo launch vehicles to satisfy the full spectrum of NASA exploration mission ETO requirements in a cost-effective manner. All of the propulsion components such as the CEV launcher have flight-proven, human-rated heritage. Preliminary reliability estimates indicate the LOV rate would be approximately 1/630 with a J-2S upper stage, making the in-line medium-lift SDLV an attractive option as a CEV launcher. The immediate availability of the key CEV launcher components could facilitate early flight demonstrations to support CEV development and test, as well as lunar precursor missions. Having such in-line medium-lift SDLV flights manifested during the "flyout" portion of the current STS significantly increases the effectiveness and commitment of the Shuttle team for the later flights. In addition to supporting exploration missions beyond LEO, the in-line medium lifter could also be used to support ISS requirements for crew and cargo resupply.



1st Stage	4-Segment RSRM
2nd Stage	J-2S Engine LO_2/H_2 (436 s Isp)
Orbit	220 x 220 nmi
CEV System	59,000 lbm*
CEV Weight to Orbit (220 nmi circular at 28.5 deg)	22 MT (48,000 lbm)
Reliability (LOV)	1/632

* Includes 10,000 lbm crew escape propulsion system plus 1,810 lbm of circularization propellant

Figure 5. The in-line medium-lift SDLV option uses mature, human-rated propulsion elements for a high-reliability CEV launcher.



Vehicle Description	
Stage 1	Expendable SRB
Stage 2	New J-2S Stage
Payload Fairing	5 m x 19 m
Mission	Medium Lift & CEV Carrier
Performance Summary	
Payload	34,486
Orbit	220 x 220 nmi @ 28.6
T/W @ Liftoff	
Max q (nominal)	1,100 psf
Max g's (nominal)	
Fairing Separation	300,000 ft
Mass Properties Summary*	
GLOW	1,616,898
SRB Inert Weight	179,825
SRB Propellant	1,105,794
2nd Stage Inert Weight***	40,476
Total Propellant Weight	245,000
Usable Propellant	
No. Engines	1
RCS	1,314
1/2 Interstage	
Payload Adapter & Avionics	1,691
Fairing	8,313
Injection Stage Cutoff Weight	
Payload Fuel to Circularize** (30 x 220 nmi)	1,314
*All weight in lbm	
** Fuel to circularize has been subtracted from stated payload	
*** Includes fuel bias, residuals, and contingencies	

HB4T212006

Figure 6. The in-line medium-lift SDLV option offers a significant cargo capability for early demonstrations and precursor missions.

C. In-Line Heavy Lifter (more than 100 metric ton payloads to LEO)

In-line heavy-lift SDLV concepts can achieve payload capabilities in excess of 110 MT by adapting flight-proven and reliable hardware and modifying existing infrastructure. These in-line heavy-lift SDLV configurations offer a wide range of payload options based on existing or modified SSME, SRB, and ET elements combined with a new cryogenic liquid propellant upper stage. Such ultra-heavy configurations would require the development of a new in-line core stage as an evolution of the current ET, based on existing tooling and manufacturing processes coupled to mature boosters, rocket engines, and tanks. The basic in-line heavy-lift SDLV concept would use a pair of five-segment SRBs combined with a core stage using a standard ET volume mounting four SSMEs, plus an upper stage using a single J-2S engine (Fig. 7). This configuration is estimated to yield 103 MT to LEO, with a payload volume that is 9 meters in diameter by 35 meters in length. Preliminary reliability estimates indicate the LOV rate would be approximately 1/130 to 1/170, depending on configuration and operational details. Considerable development schedule, cost, and risk would be avoided by taking advantage of existing long-lead elements such as rocket engines and boosters, enabling a first flight test capability in 60 months from the start of FSD.

There is a great deal of flexibility inherent in the in-line heavy-lift SDLV concept. The large payload diameters offered by in-line heavy-lift SDLV concepts are of particular interest for Mars missions. Although the need date for this class of launch capability may be several years away, this family of SDLV concepts can easily evolve from the medium payload class to the super-heavy class using the same basic engines, SRB, and subsystems currently existing in the STS inventory. Variations of the in-line heavy-lift SDLV concept involve flying with no SRB, replacing the SSME engines on the core stage with RS-68 rocket engines, flying with no upper stage, or replacing

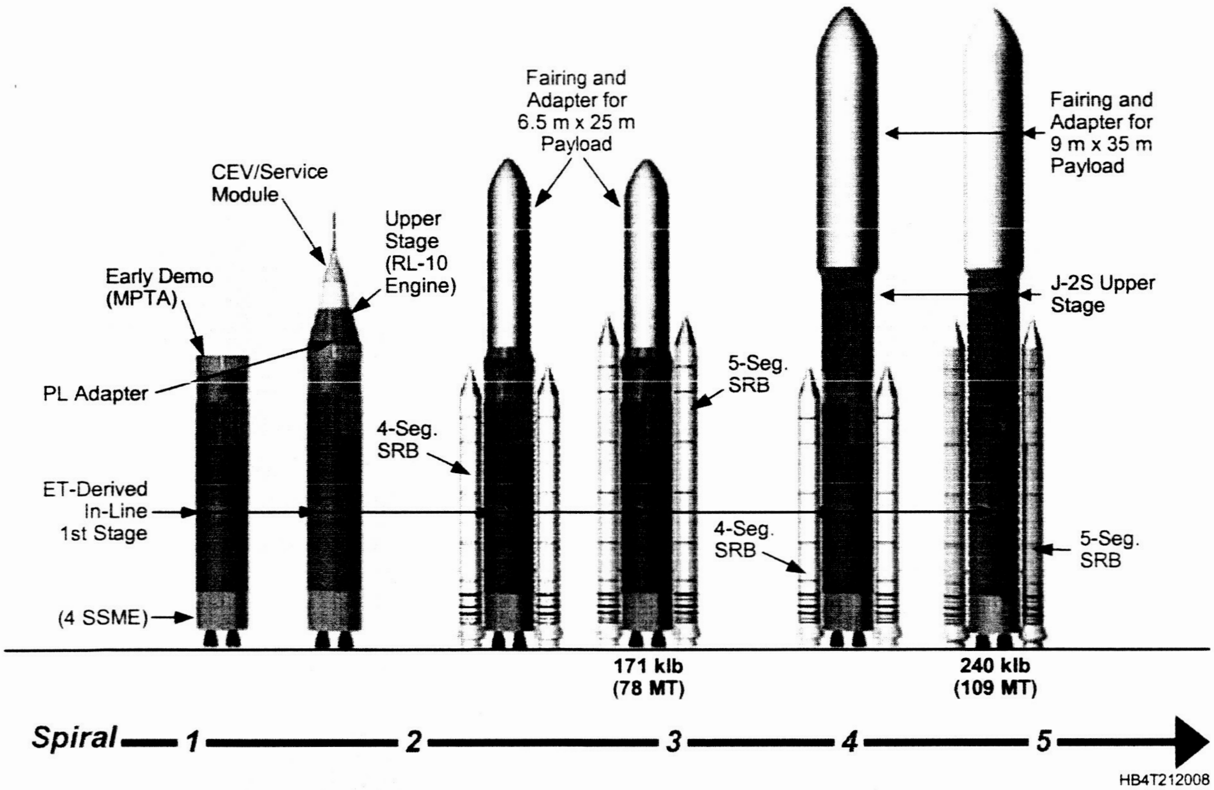


Figure 8. The in-line heavy-lift SDLV option offers logical evolution paths for each of the exploration spirals.

to those of current Mission Control Center (MCC) positions would still be required. However, since interaction with the SDLV would be minimal after launch, their tasks are greatly simplified; and many positions may be combined. In addition, flight control positions that monitor the crew activities and health status, or communicate with crewmembers, would no longer be needed for the uncrewed SDLV.

Leveraging existing assets and associated infrastructure is a key tenet of the SDLV concept. The SDLV makes maximum use of Shuttle flight hardware and existing production and operations infrastructure assets to reduce initial DDT&E and procurement costs. It is recognized that those facilities necessary to support the SDLV system will require ongoing maintenance and refurbishment, and these activities have been included in the SDLV operations cost estimates. Initial trade studies indicate that the reusable SRBs offer lower life cycle costs (LCC) than expendable SRBs for a 20-mission total life cycle. This is due primarily to the cost of expending hardware on each flight. There is limited existing hardware available, and significant new SRB hardware would have to be procured to allow currently reused hardware to be expended on each flight. Reuse also provides a significant reliability benefit by allowing the SRB hardware to be evaluated after each flight. Production costs for the SSME, SRB, and ET elements are highly sensitive to production rates. Program LCC can be dramatically reduced by adopting a "build-ahead" philosophy to optimize the production process to yield a most economic build rate. Standardizing payload to launch vehicle interfaces and operations provides significant cost benefits by allowing simplification of off-the-shelf processes and products. Subsequent reduction in the workforce required would also be realized. Maintaining operational margins and envelopes not only reduces rework costs but also provides more efficient and timely execution of processes and products.

By eliminating so many Shuttle orbiter operations cost elements, standardizing payload to launch vehicle interfaces, allowing optimum production build rates, and focusing on process improvements, the SDLV concepts are estimated to offer an order of magnitude reduction in recurring costs compared to the current STS baseline.

E. Technology Readiness Level and Technical Risks

The SDLV concepts are based on application of mainly existing assets to reduce development time, costs, and risks. Depending on the many configuration options selected, the main SDLV developmental activities could involve a new upper stage with a new rocket engine, along with a new avionics and flight software architecture.

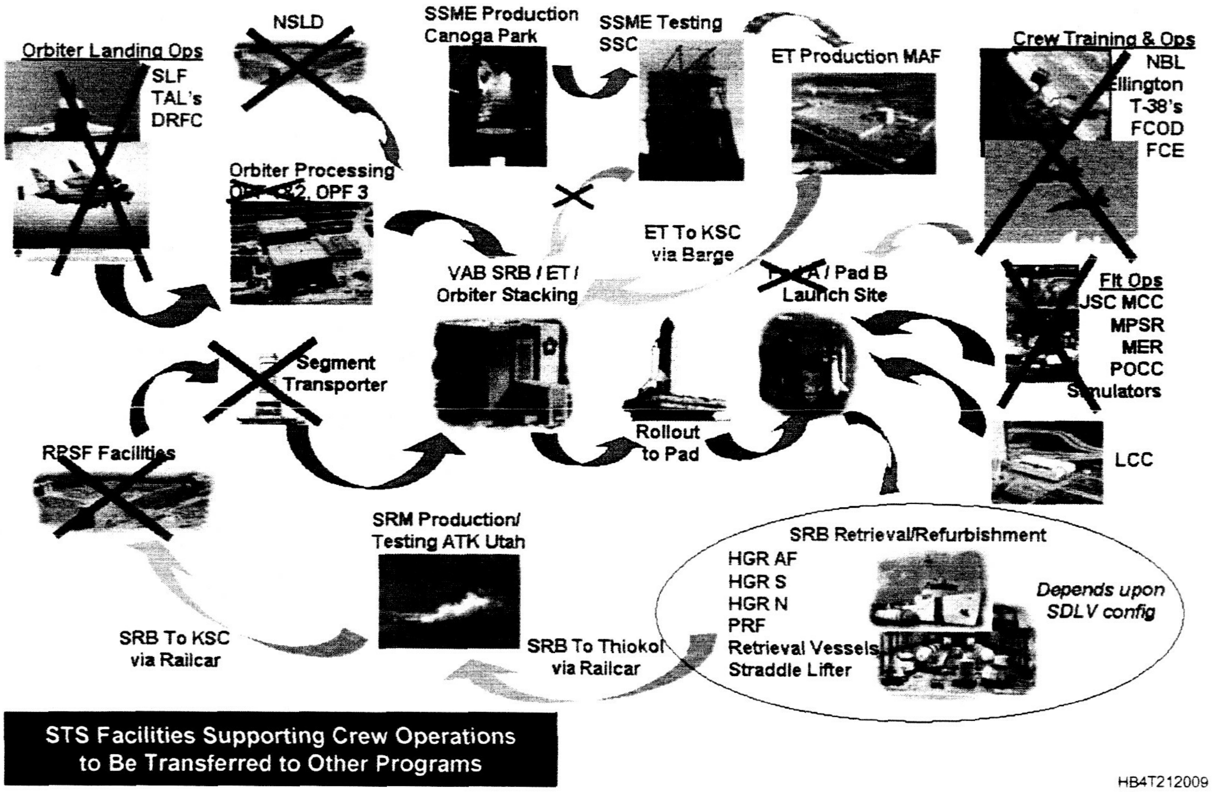


Figure 9. SDLV could greatly simplify operations by eliminating a large number of facilities and processes, dramatically reducing recurring costs compared to current STS operations.

While these are relatively mature technology areas, there are always risks involved in any engineering development program. A preliminary risk assessment by the SDLV industry team has identified several key technical risks (Fig. 10). The highest technical risk area for all of the SDLV configuration options appears to be the development and certification of the avionics architecture and flight software. There are viable mitigation plans for each of these risks, making the overall technical risk to develop any of the SDLV concepts relatively low.

F. Payload Size vs. Mission Risk

The SDLV concepts are capable of delivering very large payloads to LEO in the 60–100 MT class. Although the International Space Station (ISS) program is a marvel of systems engineering and has proven that a highly complex spacecraft can be successfully assembled in LEO, there are significant integration costs for this approach. Assembling these smaller elements together has required a considerable amount of resources and documentation to plan, develop, process, and test each element to ensure that they meet the interface requirements of the mating elements as well as the overall system. Once the elements are delivered to orbit, numerous, complex rendezvous, docking, and extravehicular activities (EVAs) are required to assemble the individual elements. Although the skilled astronauts and MCC staff make these interfaces look easy, they require months of planning and preparation to successfully accomplish. EVAs significantly impact the crew timelines, both during training on the ground and during the mission itself. The capability to deliver very large payloads to LEO should reduce the complexity of the payloads and improve the expected success rate for the exploration mission operations.

The number of launches required over a 10-year lunar exploration campaign has a very strong bearing on the overall risk of mission failure. Assume SDLV launchers deliver 60–85 MT payloads to LEO with a per-launch reliability of 0.995. A 10-year lunar campaign would require a total of 20 SDLV launches, resulting in a 9.1 percent probability of losing one payload. For comparison, a launcher that could deliver 40 MT payloads to LEO with a 0.980 percent per-launch reliability would require 40 launches over a 10-year lunar campaign, with a 55.4 percent probability of losing one payload. In addition to the cost of the lost payload, a major launch vehicle accident would

Common Technical Risks

1. Rehosting Shuttle flight software into new computer hardware and code
2. Availability / produceability of STS avionics
3. STS/EELV avionics Interface differences
4. MPS produceability and certification
5. Performance of EELV DMS computers

In-Line Medium Technical Risks

11. Development and verification of ground software
12. Development of a new upper stage
13. Certification of J-2S rocket engine
14. High dynamic pressure and L/D may induce controllability challenges
15. Booster flight environments

Side-Mount Heavy Technical Risks

6. Separation dynamics
7. Large composite fairing
8. Effects of multiple vs. unitary payload
9. Low APS thrust / weight and delta velocity capability
10. Development and verification of ground software

In-Line Heavy Technical Risks

16. Effects of multiple vs. unitary payload
17. Certification of J-2S rocket engine
18. Development of a new upper stage
19. Development and certification of 5-segment SRB
20. Development and certification of expendable SSME

HB4T212010

Figure 10. SDLV concepts use mature systems and proven processes that offer relatively low technical risks.

most likely result in a program standdown for 2 years before returning to flight operations. A 2-year standdown of the exploration program could cost many billions of dollars. The reduced number of launches and the high reliability offered by SDLV concepts would have a highly beneficial effect on the expected mission loss rate and the resulting cost of unreliability over a 10-year lunar exploration campaign.

G. Sustainability

The Vision for Space Exploration must be executed in a sustainable fashion to garner and retain the long-term support of the nation and the world for such a massive endeavor. The SDLV concept supports the sustainability issue from many aspects. SDLV supports transition of resources from the SSP to the exploration program by retaining critical skills that would otherwise leave the "sunset" Shuttle at a time when Shuttle's completion of ISS assembly is the first step in the exploration program. The SDLV concept would retain a portion of this skilled workforce and softens the impact of the SSP ending in key congressional districts in California, Utah, Texas, Louisiana, Mississippi, Alabama, and Florida (Fig. 11). An orderly transition to SDLV provides a safe and gradual draw down of the government's largest operational space system, the Space Shuttle. Management of the transition process focuses on the following objectives:

- Meet mission and safety objectives in the SSP through its final flight
- Maintain critical skills and workforce motivation
- Retain critical supply chains
- Ensure efficient and cost-effective transfer of needed assets

Without an SDLV, the phaseout of current Shuttle capabilities will begin, some gradually and others more abruptly. The Michoud facility will begin a closeout process as assembly of the last Shuttle ET is started. A similar fate is facing the large solid rocket motor manufacturing facilities in Utah. The beginning of the closure process for these unique facilities and their suppliers is within the next several years unless redirection is received. Critical suppliers will eliminate capabilities due to a lack of business to keep those capabilities in place. There are numerous assets and capabilities that will start to disappear without active NASA intervention. Without timely decisions to retain critical facilities and suppliers, the cost and risks involved in restarting these capabilities after a significant hiatus could be prohibitive. Thus, failure to make timely decisions about SDLV could be a de facto decision. A robust transition planning process would clearly identify the SSP capability decrements and the SDLV capability requirements to permit informed decision making by the agency, congress, and the administration.

- The large payload size and mass offered by SDLV concepts could substantially reduce exploration mission complexity and operational risks.
- Using high-reliability STS propulsion elements and subsystems that are already human rated offers the opportunity to develop derivative launch vehicles that could carry crew as well as cargo.
- Using proven, and well-understood, STS systems should reduce SDLV development risks and costs compared to developing new launch systems.
- SDLV concepts offer flexibility for early initial operational capability, with logical spiral development paths to reduce program risks as the exploration missions evolve and requirements mature.
- Using existing STS assets offers the opportunity to do rapid demonstrations and early flight tests, yielding credibility and sustained program support.
- There are viable technical and management approaches that could dramatically reduce SDLV annual recurring costs compared to the current STS operations.
- Developing SDLV concepts in parallel with STS operations would allow an orderly transition, taking advantage of a large body of expertise with demonstrated capabilities for space systems development and operations to retain critical skills and avoid Shuttle safety degradations.
- The SDLV industry and NASA teams have worked together effectively to explore a wide range of STS-Derived Launch Vehicle concepts.

HB4T212011

Figure 11. SDLV Collaborative Study Teams' Key Findings.

The ability to meet SSP safety objectives would be improved with an orderly transition to an SDLV to ensure the assets required to develop and operate an SDLV would continue to be well maintained through the life of the current SSP. A NASA Headquarters transition team is expected to manage the cross-program dependencies to make decisions in the best interest of the nation. Each affected program, SSP and SDLV, would have representation on this transition team to coordinate the effort for each program and maintain frequent communication about each other's plans and requirements. The SSP transition team would identify all SSP assets and their "last need-date," along with overseeing the orderly decommissioning of those assets. The SDLV transition team would ensure timely identification of SSP asset requirements and schedules to support the SDLV development, production, and operations needs, along with overseeing a smooth transfer of responsibilities for those assets. Overlaying the SSP retirement and the SDLV development schedules provides the basis for the many maintain, scrap, or buy decisions. In addition, the overlay of workforce requirements shows how critical skills and assets would be impacted such that informed retention decisions could be made. Upgrade and maintenance investments could be made knowing that the life of those assets extends beyond the current STS program end date. The NASA Headquarters transition team will make decisions on which program bears the cost responsibility if it is unclear.

IV. Summary

There have been a number of parallel activities pursued by several government and industry teams over the past year evaluating a wide range of SDLV approaches. The results of these independent studies have shown remarkably good correlation. Collaborative efforts between the government and industry study teams have identified several areas worthy of more detailed study. These government and industry studies have concluded that there are a number of viable SDLV concepts offering attractive options for ETO launch services. These SDLV concepts support NASA's Space Exploration Vision in the following important ways:

- The large payload size and mass offered by SDLV concepts could substantially reduce exploration mission complexity and operational risks.
- Using high-reliability STS propulsion elements and subsystems that are already human rated offers the opportunity to develop derivative launch vehicles that could carry crew as well as cargo.
- Using proven, and well-understood, STS systems should reduce SDLV development risks and costs compared to developing new launch systems.

- SDLV concepts offer flexibility for early initial operational capability, with logical spiral development paths to reduce program risks as the exploration missions evolve and requirements mature.
- Using existing STS assets offers the opportunity to do rapid demonstrations and early flight tests, yielding credibility and sustained program support.
- Viable technical and management approaches could dramatically reduce SDLV annual recurring costs compared to the current STS operations.
- Developing SDLV concepts in parallel with STS operations would allow an orderly transition, taking advantage of a large body of expertise with demonstrated capabilities for space systems development and operations to retain critical skills and avoid Shuttle safety degradations.