Access to Space: The Future of U.S. Space Transportation Systems

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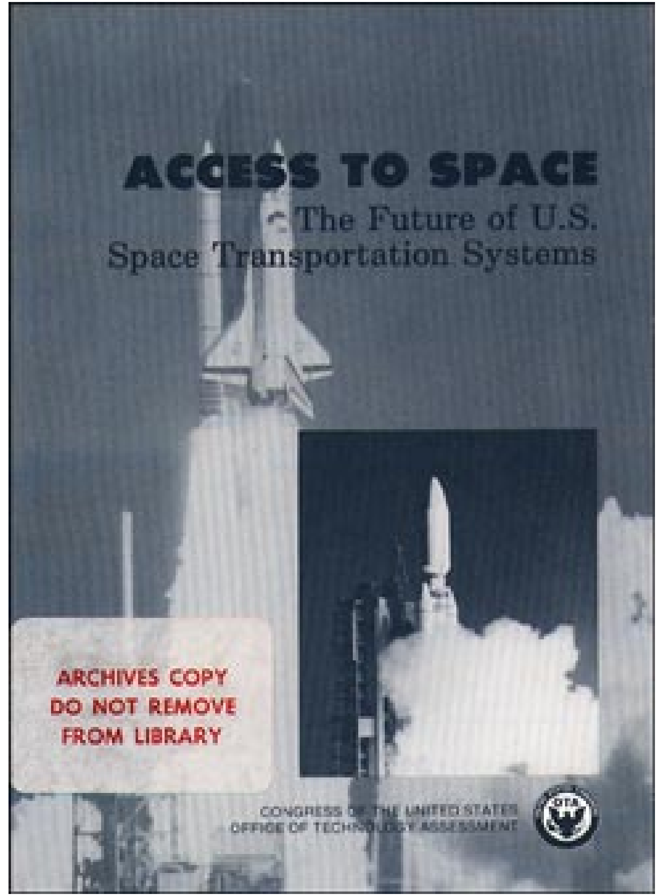

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Foreword

The United States today possesses a capable fleet of cargo and crew-carrying launch systems, managed by the National Aeronautics and Space Administration, the Department of Defense, and the private sector. Emerging technologies offer the promise, by the turn of the century, of new launch systems that may reduce cost while increasing performance, reliability, and operability.

Continued exploration and exploitation of space will depend on a fleet of versatile and reliable launch vehicles. Yet, uncertainty about the nature of U.S. space program goals and the schedule for achieving them, as well as the stubbornly high cost of space transportation, makes choosing among the many space transportation alternatives extremely difficult. Can existing and potential future systems meet the demand for launching payloads in a timely, reliable, and cost-effective manner? What investments should the Government make in future launch systems and when? What new crew-carrying and cargo launchers are needed? Can the Nation afford them?

This special report explores these and many other questions. It is the final, summarizing report in a series of products from a broad assessment of space transportation technologies undertaken by OTA for the Senate Committee on Commerce, Science, and Transportation, and the House Committee on Science, Space, and Technology. In the course of the assessment, OTA has published the special reports, *Launch Options for the Future: A Buyer's Guide* and *Round Trip to Orbit: Human Spaceflight Alternatives;* the technical memorandum, *Reducing Launch Operations Costs: New Technologies and Practices;* and the background papers, *Big Dumb Boosters: A Low-Cost Space Transportation Option?* and *Affordable Spacecraft: Design and Launch Alternatives.*

In undertaking this effort, OTA sought the contributions of a wide spectrum of knowledgeable individuals and organizations. Some provided information, others reviewed drafts. OTA gratefully acknowledges their contributions of time and intellectual effort. OTA also appreciates the help and cooperation of NASA and the Air Force. As with all OTA reports, the content of this special report is the sole responsibility of the Office of Technology Assessment and does not necessarily represent the views of our advisors or reviewers.

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NOTE: OTA appreciates the valuable assistance and thoughtful critiques provided by the advisory panel members. The views expressed in this OTA report, however, are the sole responsibility of the Office of Technology Assessment. Participation on the advisory panel does not imply endorsement of the report.

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Related OTA Reports

Civilian Space

Advanced Space Transportation Technologies Assessment

- *Affordable Spacecraft: Design and Launch Alternatives. OTA-BP-ISC-60,* January 1990. GPO stock #052-003-01 174-3; $2.25.
- *Round Trip to Orbit: Human Spaceflight Alternatives. OTA-ISC-419,* August 1989, GPO stock #052-003-01 155-7; $5.50.
- *Launch Options for the Future: A Buyer's Guide. OTA-ISC-383,* July 1988. NTIS order #PB 89-1 142681AS.
- *Reducing Launch Operations Costs: New Technologies and Practices. OTA-TM-EC-28,* September *1988. GPO* stock #052-003-01 118-2; $4.50.
- *Big Dumb Boosters: A Low-Cost Space Transportation Option?* OTA Background Paper, February 1989. (available from OTA's International Security-and Commerce Program)

Other Reports

- *Commercial Newsgathering From Space. OTA-TM-ISC-40,* May *1987.* NTIS order #PB 87-235 396/XAB.
- *Space Stations and the Law: Selected Legal issues. OTA-BP-ISC-41,* September 1986. NTIS order #PB 87-118 220/AS.
- *International Cooperation and Competition in Civilian Space Activities. OTA-ISC-239,* July 1985. NTIS order #PB 87-136 842/AS.
- *U.S.-Soviet Cooperation in Space. OTA-TM-STI-27,* July 1985. NTIS order #PB 86-114 758/AS.
- *Civilian Space Stations and the U.S. Future in Space.* OTA-STI-241, November 1984. GPO stock #052-003-00969-2; $7.50.
- *Remote Sensing and the Private Sector: Issues for Discussion. OTA-TM-ISC-20,* March 1984. NTIS order #PB 84-180 '777.
- *Salyut: Soviet Steps Toward Permanent Human Presence in Space.* OTA-TM-STI- 14, December 1983. NTIS order #PB 84-181 437/AS.
- *UNISPACE '82: A Context for International Cooperation and Competition. OTA-TM-MC-26,* March 1983. NTIS order #PB 83-201848.
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- *Civilian Space Policy and Applications. OTA-STI-177,* June 1982. NTIS order #PB 82-234444.
- *Radio frequency Use and Management: Impacts From the World Administrative Radio Conference of 1979. OTA-CIT-163,* January 1982. NTIS order #PB 82-177536.
- *Solar Power Satellite Systems and Issues.* OTA-E-144, August 1981. NTIS order #PB 82-108846.

Military Space

- *SDI: Technology, Survivability, and Softwre. OTA-ISC-353,* May 1988. GPO stock #052-003-01084-4; $12.00.
- *Anti-Satellite Weapons, Countermeasures, and Arms Control. OTA-ISC-281,* September 1985. NTIS order #PB 86-182 953/AS.
- *Ballistic Missile Defense Technologies. OTA-ISC-254,* September, 1985. NTIS order #PB 86-182 961/AS.
- *Arms Control in Space. OTA-BP-ISC-28,* May 1984. NTIS order #PB 84-198 209/AS.
- *Directed Energy Missile Defense in Space. OTA-BP-ISC-26,* April 1984. NTIS order #PB 84-21011 I/AS.

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Legislative Options for Space Transportation

Space Program Futures

Congress could choose to support the development of one or more of many different types of space transportation systems. To determine which of these alternatives is most appropriate, Congress must first make some broad decisions about the future of the United States in space. A commitment to key space program goals will entail a similar commitment to one or more launch systems.

[f Congress wishes to:	*Then it should:*
Limit the expansion of NASA and DoD space programs:	*Maintain existing launch systems and limit expenditures on future development options.* **Current capabilities are adequate to supply both NASA and DoD if the present level of U.S. space activities is maintained.**
Develop the capability to launch small- and intermediate-size payloads quickly and efficiently to support DoD and civilian needs:	*Continue to support the development of small and intermediate capacity launch systems.* **The U.S. private sector has the financial and technical capacity to develop such systems on its own if a market for launching small payloads exists.**
Deploy Space Station *Freedom* by the end of the century, while maintaining an aggressive NASA science program:	*Continue funding improvements to the Space Shuttle and other existing space transportation systems and/or begin developing Shuttle-C:* **The existing Space Shuttle can launch the Space Station, but will do so more effectively with improvements or the assistance of a Shuttle-C. Although Shuttle-C might not be as economical as other new cargo vehicles at high launch rates, it would be competitive if only a few heavy-lift missions are required each year.**
Continue trend of launching heavier communications, navigation, and surveillance satellites and/or pursue an aggressive Strategic Defensive Initiative test program:	*Commit to the development of a new cargo vehicle for use early in the 21st century.* **Although existing launch systems could be expanded to meet such growth in payload weight, if demand is high, new, advanced systems would be more reliable and cost-effective.**
Deploy a full-scale space-based ballistic missile defense system and/or dramatically increase the number and kind of other military space activities:	*Commit to the development of a new cargo vehicle such as the Advanced Launch System.* **Current launch systems are neither sufficiently economical to support full-scale space-based ballistic missile defense deployment, nor reliable enough to support a dramatically increased military space program.**
Establish a permanent base on the Moon or send humans to Mars:	*Commit to the development of a new cargo vehicle(s) (Shuttle-C, Advanced Launch System, or other system) and continue funding advanced, crew-carrying launch systems.* **Any major initiative beyond the Space Station involving humans in space will require new launch systems.**

Improving U.S. Space Transportation Systems

Whichever broad program goals are selected, if Congress wishes to continue to improve the safety, reliability, performance, and/or economy of U.S. launch systems, it has a number of possibilities from which to choose. Several are listed below; they are not mutually exclusive, nor is the list exhaustive. Congress could decide to proceed with one or more from each list of options. Because of the long lead times for the development of space transportation systems, some decisions will have to be made in the next year or two. Others can wait until the middle of this decade or later.

Near-Term Decisions

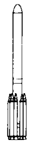
If Congress wishes to:	*Then it could:*
Improve cargo launch system reliability or performance:	• *Fund development of technologies in the Advanced Launch System and other programs.*
Improve Space Shuttle system safety, reliability:	. *Fund development of Liquid-fueled Rocket Boosters (LRBs).* . *Fund continued development and improvement of Advanced Solid Rocket Motors (ASRMs) and alternate turbopumps for the Space Shuttle Main Engines.* . *Fund installation of built-in test equipment in the Shuttle and more automated test equipment in launch facilities.*
Maintain a sustainable Shuttle launch rate of 9 to 11 launches per year:	• *Fund the purchase of at least one additional orbiter to be delivered as soon as possible (1996), and direct NASA to reduce the number of Shuttle flights planned per year. NASA could reduce Shuttle flights by:* *a. postponing or canceling some planned Shuttle launches; or* *b. relying more on cargo-only launch vehicles, such as Titan IVs.*
Reduce risks to successful Space Station assembly:	. *Direct NASA to develop and use Shuttle-C to carry some Space Station elements to orbit. (This would reduce the total number of flights required.)*
Develop the technology base and plan for building new crew-carrying launch systems:	• *Continue to fund planning and technology development and test efforts such as:* *a. the Advanced Manned Launch System studies;* *b. the National Aero-Space Plane program (NASP); or* *c. the Advanced Launch System (ALS) program.*
Provide for emergency crew return from the Space Station:	• *Fund a program to develop a U.S. crew emergency return vehicle.* • *Support joint development with Space Station partners of vehicle for emergency return.*

Far-Term Decisions

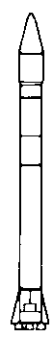
If Congress wishes to:	*Then it could:*
Build safer, more reliable crew-carrying launch systems:	• *Fund development of safer, more reliable launch systems to augment or succeed the Shuttle. These might include:* *a. a Personnel Launch System (PLS), or* *b. an Advanced Manned Launch System (AMLS), or* *c. vehicles derived from the National Aero-Space Plane (NASP) program.*
Improve cargo launch system reliability and reduce costs:	. *Fund development of launch vehicles or systems (e.g., ALS engines) that could be manufactured, integrated, and launched by highly automated methods with improved process control.*
Increase operability:	• *Fund development of vehicles designed for quick turnaround, such as those considered for an Advanced Manned Launch System or possible successors to the proposed National Aero-Space Plane test vehicle (X-30).*

Major Launch Systems Discussed in This Report:

Existing Systems

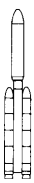


Delta II Expendable Launch Vehicle **(ELV)—manufactured by McDonnell** Douglas, it is capable of lifting over 11,000 pounds to low Earth orbit (LEO). Developed for the U.S. Air Force from earlier Delta versions, the Delta II is also available commercially from McDonnell Douglas. Its first launch took place in August, 1989.

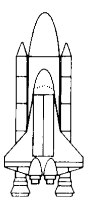


Atlas II ELV---capable of lifting about 14,500 pounds to LEO. Manufactured by General Dynamics under contract to the Air Force, the Atlas is also available in a commercial version from General Dynamics. Its first commercial launch is scheduled for summer, 1990.

Titan III ELV—a commercial launch vehicle capable of lifting up to 32,500 pounds to LEO, manufactured by Martin Marietta. Its first commercial launch occurred on December 31, 1989.

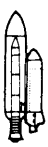


Titan IV ELV—manufactured by Martin Marietta under contract to the U.S. Air Force, it is capable of lifting about 39,000 pounds to LEO. It was first launched on June 14, 1989, and carried a military payload.

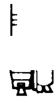


Space Shuttle—a piloted, partially reusable launch vehicle capable of lifting about 52,000 pounds to LEO. The Shuttle fleet now consists of three orbiters; a fourth is being completed.

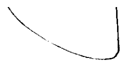
Potential Future Launch Systems



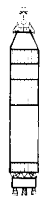
Shuttle-C-an unpiloted cargo vehicle, derived from Shuttle systems, with a heavy-lift capacity of up to 150,000 pounds to LEO. It would use the existing expendable external tank and reusable solid rocket boosters of the Shuttle, but replace the orbiter with an expendable cargo carrier.



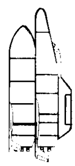
Advanced Launch System (ALS)--a totally new modular launch system under study by the Air Force and NASA. ALS would be capable of launching a range of cargos at high launch rates and reduced costs.



Crew Emergency Return Vehicle-a vehicle that would provide for crew escape and return from the Space Station, independent of the Shuttle, in case of crew medical emergencies or major Space Station failures.

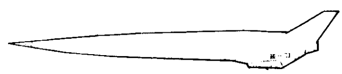


Personnel Launch System (PLS)--a new concept for a crew-carrying vehicle launched atop expendable launch vehicles. It would be less complex and less expensive than the Shuttle. A PLS could transport crew to and from space, and might also serve as an emergency return vehicle.



Advanced Manned Launch System (AMLS)—an advanced successor to the Shuttle, available after the year 2005. System concepts vary from partially reusable through fully reusable vehicles.

National Aero-Space Plane (NASP)



—a proposed reusable vehicle that could be operated like an airplane from conventional runways, but fly to Earth orbit powered by air-breathing, or air-breathing/rocket engines. The Air Force and NASA are working on designs for an experimental version of this vehicle, the X-30.