Introduction, Background, and Findings

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Reductions in space and defense spending over the last decade and a lack of consistent policy toward space transportation research and development have proved challenging for the U.S. space transportation industry. The lower tiers of the space transportation technology and industrial base have been especially affected.

Although a number of studies have assessed the viability of the space transportation technology and industrial base, they have focused on the large prime contractors that integrate and assemble space transportation systems--expendable launch vehicles (ELVs), reusable launch vehicles (RLVs), and long-range ballistic missiles. [1]

The studies have all but ignored the lower tiers of this base, i.e., the firms that supply most of the subsystems, components, and parts used in space transportation systems, despite the fact that these firms collectively account for roughly half of the value added to space transportation systems. OTA's research suggests that these lower-tier firms are feeling disproportionate pain from defense cuts, but are largely overlooked by policymakers in Washington.

The U.S. aerospace industry as a whole is downsizing, rationalizing, and reducing the number of lower-tier suppliers, in part to achieve economies of scale. The space transportation industrial sector is already characterized by relatively small production vol -

"... failure or withdrawal of a single supplier.. could cause delays in important programs, significant unexpected future expense, and reliability concerns ...."

[1] Space transportation in this background paper refers to vehicles able to carry payloads or passengers to orbit. This background paper does not address suborbital launch systems or transportation systems designed primarily to move payload or passengers between or beyond Earth orbits. Currently, the partially reusable U.S. Space Shuttle is the world's only operational RLV.

umes and few suppliers of many subsystems and components. Reductions in the number of space transportation suppliers largely reflect a lack of business, rather than a drive to compete more effectively.

As congressional and executive branch policymakers head toward a new millennium, a major concern will be whether factors, such as limited demand, skepticism about government intentions, strained relations with prime contractors, and the perceived ineffectiveness of government procurement reform, will compel key firms and the capabilities they embody to abandon the space transportation market altogether. Policymakers will need to know if sufficient suppliers will be available at an acceptable cost to support the nation's space transportation requirements. And they will need to know how their policies, traditionally crafted with prime contractors in mind, will affect the half of space transportation dollars represented by the lower industrial tiers.

BACKGROUND

At the request of the House Science Committee, OTA is conducting an assessment of the current and future health of the U.S. space transportation technology and industrial base.[2] The study encompasses all aspects of the U.S. space transportation base, including research and development (R&D), production, operations, maintenance, acquisition, and management. It also addresses the entire spectrum of commercial, civil, defense, and intelligence space transportation systems, both expendable and reusable, as well as long-range ballistic missiles.

The federal government is a main customer and regulator for space transportation systems and services and has heretofore paid most development costs. Government actions and policies, therefore, have a direct and often overwhelming impact on the space transportation industrial base.

As part of this assessment, an OTA workshop examined the current status of lower-tier firms, those companies that provide either hardware or services to the handful of prime contractors who supply space transportation systems (see box 1-1). Lower-tier firms provide about 50 percent of the value added to aerospace systems, as well as hardware, software, and materials without which there would be no finished products. For this reason alone, understanding the lower industrial tiers is crucial to understanding the space transportation technology and industrial base as a whole.

In addition to those who attended the workshop, OTA interviewed representatives of two dozen other lower-tier firms. While OTA recognizes that this industry sample was not selected randomly and hence the findings are not necessarily generalizable to the industry as a whole, participants were selected from the full range of providers of space transportation subsystems, components, and parts, and services, and from basic commodity to major system manufacturers.

In addition, this background paper was reviewed by members of the full assessment's Advisory Panel, participants in the lower-tier workshop, and others.

The remainder of this chapter summarizes the main findings of this paper. Chapter 2 discusses the definition and significance of the lower tiers, special features of the space transportation industrial base, and recent studies of the space launch industry. Chapter 3 presents some of the workshop discussion in more detail.

FINDINGS

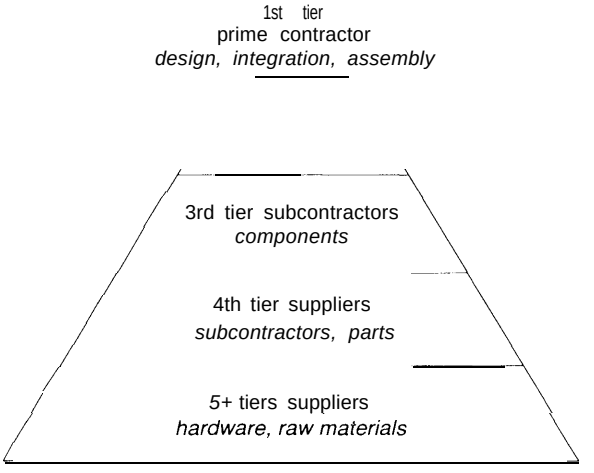
1. **Many of the lower-tier manufacturing firms that supply space transportation system parts, components, and subsystems are not diversified and depend heavily on the launch vehicle, missile, and related military markets. These firms share a pessimistic**

[2] The first report of this assessment was published in May 1995. It examines the Clinton Administration's new space transportation policy and implementation plans and raises issues of particular interest to Congress. See U.S. Congress, Office of Technology Assessment, *The National Space Transportation Policy: Issues for Congress*, OTA-ISS-620 (Washington, DC: U.S. Government Printing Office, May 1995).

BOX 1-1: The Industrial Tier Structure

In this background paper, the terms "prime" or "prime contractor" denote the first-tier firms responsible for the final assembly and integration of space transportahon systems These systems are sold by the prime contractor to commercial and government customers, either directly or in the form of launch services

Simplified Industrial Tier Pyramid



The lower tiers of the space transportation industry pyramid begin with subcontractors that manufacture major subsystems and components of space transportation systems, and extend to suppliers of parts, hardware, and basic commodities, who may be five or more tiers removed from the primes The common distinguishing characteristic of lower-tier firms is that they sell to the prime contractor or to other lower-her firms, rather than directly to space transportation customers.

SOURCE Off Ice of Technology Assessment, 1995

view of their future business prospects. Some other firms, however, have significant non-government business, enabling them to respond with somewhat more flexibility to the decline of their government launch vehicle and missile work. Attrition is high among all lower-tier firms: new suppliers may have to be found within five years for 35 to 40 percent of critical subsystems and components currently being procured for use in Department of Defense (DOD) launch vehicles.

A majority of the manufacturing firms in the workshop depend on government orders for 75 to 100 percent of their gross income in the space and missile field. Several see no future business at all in space transportation. One heavily government-dependent firm, part of a larger entity, closed its plant shortly after the workshop. Its last, large program had come to an end, with no follow-on business in sight. It was one of only two firms capable of producing its principal product.

All of the firms report significant downsizing in their government operations over the past sev-

TABLE 1-1: U.S. Expendable Launch Vehicle Flights

	1991	1992	1993	1994
DOD	8	10	8	12
NASA	2	5	5	4
Commercial	1	2	3	4
TOTAL	11	17	16	20

SOURCE National Aeronautics and Space Administration, *NASA Pocket Statistics,* 1995, p B-4

eral years—typically, staffs have been reduced by 30 to 60 percent. This downsizing appears to result principally from the decrease in defense orders and the small, albeit slightly growing, demand for space transportation (see table l-l).

At least two firms represented at the workshop have successfully reduced their dependence on government business, although it still makes up an important share of their work. One other firm, which provides essential equipment for both U.S. and foreign launch systems, also has a very strong business base in non-aerospace activities. Conversely, only one very small firm, which is entirely dependent on space transportation business, reports itself entirely satisfied with both the size and nature of its government space business base.

A government participant in the workshop cited an ongoing Air Force assessment of the stability of the supply of critical space transportation subsystems and components. This study indicates that new suppliers will have to be found within 5 years for 35 to 40 percent of such items currently being procured for use in DOD launch vehicles, because present producers will no longer be producing the items in question or will be out of business.

2. **More and more launch vehicle subsystems and components are produced by only one or two U.S. suppliers. Buying from one or two suppliers may result in lower unit costs through economies of scale, and may even enhance prospects for the suppliers' survival by enlarging their business bases. On the other hand, failure or withdrawal of a single supplier, for whatever reason, could cause delays in important programs, significant unexpected future expense, and reliability concerns if a new supplier must be hurriedly qualified.**

There is a strong possibility that the market will drive out all but a single supplier of one, a few, or even many key systems, subsystems, or components. Opinions differ as to the significance of this phenomenon. In a 1995 study, DOD concludes there is no need for concern, because "the major prime [contractors and second-tier subcontractors] have demonstrated an ability to manage the risks associated with a changing vendor base."[3]

The authors of that report believe that the demand for U.S.-produced space transportation systems will continue to be sufficiently high to keep firms engaged in the market, and that any supplier problems can be satisfactorily addressed on a case-by-case basis.[4] In the past, DoD has resorted to "lifetime buys" (purchasing enough of a given item to last the expected life of the affected program) and other relatively expensive measures to ensure availability of critical components.

The views of the OTA workshop participants, however, were in notable contrast to the DOD finding. They echoed a 1992 National Space Council study that expressed concern that

> "cutbacks in government procurements... will quickly eliminate unique capabilities provided by second- and third-tier contractors, create foreign source dependencies, or even lead to production gaps ('dark factories') that can only be bridged at much greater expense than that associated with maintaining capabilities."[5]

[3] U.S. Department of Defense, *Industrial Assessment for Space Launch Vehicles* (Washington, DC: Department of Defense, January 1995), p. ES- 10.

[4] Informal DOD comments on the first draft of this report, June 7, 1995.

[5] Vice President's Space Policy Advisory Board, *The Future of the U.S. Space Industrial Base: A Task Group Report* (Washington. D.D.: The White House, November 1992), p. 25.

OTA's analysis of the space transportation industrial base, as well as its work on the defense industrial base, suggests that both views are partly valid. Given the right mix of ample funding and adequate lead-time, prime contractors can probably ensure the continued availability of critical subsystems and components, particularly if they are not constrained by technical and contractual requirements that limit their flexibility unduly.

Prime contractors, however, cannot be expected to take preventive steps to maintain lower-tier capabilities unless they can expect to profit from doing so and they have ongoing procurement contracts. For this reason, the risk is real that interruptions in the supply of critical lower-tier products could disrupt critical DOD and National Aeronautics and Space Administration (NASA) missions.

3. **The lower-tier firms do not believe that ambitious new space transportation initiatives will result in decisions to build new vehicles. Experience with past, abortive programs, ranging from Shuttle-C to the National Aerospace Plane, has convinced them that the federal government lacks both the will and the resources to produce major new vehicles or systems.**

Lower-tier firms are deeply skeptical of NASA's X-33 program, which aims to codevelop with industry a completely reusable RLV to reduce dramatically the cost of transporting payloads to orbit and eventually replace the Space Shuttle. Most are also doubtful that DOD's Evolved Expendable Launch Vehicle (EELV) program will produce a new evolutionary family of ELVs, as opposed to minor modification of existing systems. Several note disappointing experiences with previous, aborted projects, such as the National Aerospace Plane, the National Launch System, the Advanced Launch System, Spacelifter, and Shuttle-C (a cargo variant of the Space Shuttle).

Many workshop participants and reviewers felt that by trying to pursue the RLV and the EELV developments simultaneously, while continuing to operate the Space Shuttle, the United States risks arriving at the year 2000 with a design for the RLV that is too costly and not capable enough, but without an EELV. They expressed concern that the RLV development program (and the continuing operation of the Shuttle program) will capture most of the space transportation funds available in the DOD and NASA budgets. In this scenario, the United States would then be obliged to continue to rely on the Space Shuttle and minor modifications of existing medium and large ELVs.[6]

Workshop participants are also skeptical that prime contractors intend to contribute significantly to the development costs of the X-33 program. Two firms say they were approached by prime contractors to join teams competing for the X-33 procurement, but on the condition that they help fund the team's activities. They were unwilling to do so, although some lower-tier firms have made such contributions where the future market was more predictable—for example, in the development of a new commercial aircraft. One participant summed up the general view, asserting that there was no confidence that the firms would "get their money back" from such an investment.

Workshop participants also question whether, aside from classified military applications, there is sufficient heavy-payload demand to warrant spending on both the high-capacity end of the EELV range and on the medium-to-heavy X-33. They comment that small low-Earth-orbit (LEO) communications satellite systems, such as Iridium, and scientific spacecraft, such as Clementine

[6] Proponents of this view acknowledge that separate budgets are involved, but point to past experience with shared programs as evidence that the Congress tends to treat the space transportation components of the NASA and DOD budgets as closely coupled and subject to common constraints.

and the Millennium series, represent the only real growth market, and that this market can be served by medium-sized and smaller ELVs.

4. **One of the most serious problems faced by lower-tier firms is the loss (through retirement or downsizing) of experienced people, and the limited intake of young engineers and specialists. This trend is eroding the industry's knowledge base. A parallel problem is posed by the lack of investment in lower-tier manufacturing facilities, due to limited technological change in systems and general pessimism about future business.**

Companies report that lower-tier hiring of young engineers and technicians in the space transportation industry has virtually ceased for the last few years. At the same time, many of the experienced people responsible for the original design, development, and production of the current space transportation fleet have retired, while corporate downsizing has forced many of the mid-level people out of the business.

Workshop participants report that fewer than half of the people involved in their space transportation business five years ago are still in the field. Moreover, because of the lack of new projects, almost all of those younger engineers who remain have not participated in the development of a major system, which experts believe is an essential element in training a successor generation.

Firms generally say that there has been little new investment in their space transportation-related manufacturing facilities. Like the vehicles they produce, these facilities largely reflect technologies 25-30 years old. Materials and fabrication techniques have not changed significantly due to the conservative nature of the business and the lack of new space transportation development funding. With a dim view of future business prospects, lower-tier firms have little incentive to invest.[7]

5. **Lower-tier firms have not yet benefited from procurement reforms instituted by DOD and NASA.[8] The continued application of traditional government requirements and oversight, despite the reforms, has been a direct deterrent to efforts to diversify into commercial markets.**

Executives at lower-tier firms feel that prime contractors pass on or "flow down" intrusive government requirements intact, sometimes adding requirements of their own. There is a general perception that the primes are unwilling to risk procuring systems or subsystems on a commercial basis, even if the revised rules appear to permit it, because of the risk of disqualification for not complying with government requirements.

Workshop participants argue that federal procurement reforms have not materially changed the business environment for the lower-tier firms, and that the current environment deters them from efforts to diversify into commercial markets. Flowed-down federal regulatory burdens act as a tax on their products, making them noncompetitive in the commercial marketplace.

One major obstacle to diversification is the difficulty of changing lower-tier firms' corporate culture from one that is accustomed to meeting traditional government procurement requirements to one that is agile and responsive to the rapidly changing commercial market.

One workshop participant holds that it is impractical to organize a firm, or a plant, to meet both sets of requirements, and that this fact makes attempts to transition into the commercial marketplace much more difficult. Because lower-tier firms generally tend to be smaller than the primes, this is more likely to be true for the former than the latter. Lower-tier firms also cite the prohibitive cost of maintaining two production and accounting systems (one for government, the other for commercial customers) and the government's in-

[7] The lack of investment in these companies may actually compound their problems, because new manufacturing technologies could enable them to transition to lower-rate production more efficiently.

[8] See box 2-1 in chapter 2 for a brief summary of the reforms that have been undertaken.

sistence on "most favored customer" pricing as strong deterrents to moving onto a commercial footing.

6. **If low-cost, reusable space transportation systems become a reality, they may greatly reduce the demand for ELVs, resulting in a sizable shift in the make-up of the space transportation industry. First, lower-tier firms dedicated to technology applicable only to ELVs may find themselves without work, as the systems they support are displaced. Second, even companies with RLV-relevant technology will have limited production volumes as their products are reused rather than expended or replaced. Provision of spare parts for and maintenance of a relatively tiny reusable vehicle fleet may be their only source of revenue once the initial production run is completed.**

Some important lower-tier firms do not expect to benefit from a shift from ELVs to RLVs, because a next-generation reusable vehicle is unlikely to use their technology. Because of the importance of some of these firms (e.g., producers of large solid rocket motors) to long-range ballistic missiles, further impairment of these firms' business interests could have broader implications.[9] These firms believe that if there is to be any worthwhile future government business, it will come from missile programs and ELVs, rather than future reusable vehicles.

These firms believe that the Space Shuttle experience demonstrates that an RLV program is apt to over-promise, face chronic funding shortfalls, and end up requiring a large and costly "marching army" of prime contractor and NASA employees to maintain and operate the system. Firms are deeply critical of current NASA spending for Space Shuttle infrastructure, both internally and on support contracts, which they say is absorbing the funds that should be invested in new space transportation technologies and systems.

Other companies, with experience in the aircraft industry or on the Shuttle, have somewhat better expectations. Even these, however, foresee only a limited initial market, followed by a long period of high operating costs and relatively little production business for them.

7. **Relations between lower-tier firms and prime contractors are strained.[10] Lower-tier firms maintain that as the primes downsize, they become more vertically integrated and increasingly compete with their suppliers. Lower-tier managers also complain that the primes negotiate cost-plus development contracts with their customers (NASA and DOD, in particular), but negotiate fixed-price contracts with the lower tiers, shifting much of the business and technical risk onto their shoulders. Furthermore, the primes (as well as some government laboratories) often compete against their suppliers for federal R&D funds, absorb them internally, and do not pass them along to help fund lower-tier R&D.[11]**

In general, workshop participants feel that relations with prime contractors have deteriorated in recent years, reflecting the pressure of downsizing and reduced defense spending.

Lower-tier manufacturing firms report episodes in which the primes initially out-sourced components to them, inducing the lower-tier firms to invest in tooling and start-up costs, only to reverse themselves within a year or two and pull the work back in house. In some cases, this cycle occurred more than once for the same set of compo-

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[9] The Air Force is developing an ICBM Long Range Planning (ILRP) activity to address the future of the ballistic missile industrial base. Most of the focus of the ILRP currently is on reentry vehicles and guidance systems.

[10] One reviewer (at a prime contractor) sees no sign of such difficulties at his firm or between the other primes and their suppliers, but virtually all other reviewers (particularly those at lower-tier firms) support this finding.

[11] There are some cases in which the primes have established strategic relationships with key suppliers, including the sharing of R&D funding, but to date these cases appear to be fairly rare.

nents. Some believe that this happened because the primes seek, at first, to reduce the manpower impact of shrinking business by pulling as much work as possible in house. After a period, the firms discover that they are inefficient producers of some items, and decide to out-source them in order to cut costs. Then a new round of downsizing pressures hits, and the cycle repeats itself.

Lower-tier manufacturers report that the primes are not generally willing to fund any R&D by lower-tier firms, either from their own resources or by passing along government funding. Even when primes did not do the R&D by themselves, their internal bureaucratic "taxes" and those imposed by the funding agencies siphon off so much federal funding that relatively little actually reaches the lower tiers.[12]

8. Lower-tier firms are unwilling to fund R&D to meet a government requirement in the absence of a good prospect of series production, or unless the resulting product has "dual-use" potential on the commercial market. They are deeply pessimistic that such prospects exist in the space transportation business. Some firms have newer technology on the shelf, which could be incorporated in existing vehicles, but primes and/or customers are unwilling to bear the cost or risk. Meanwhile, it is increasingly difficult and costly to continue to produce antiquated systems and components.

Lower-tier manufacturing firms say that they can not justify spending corporate funds on R&D related solely to launch vehicles, because the future business potential is not large enough, or secure enough, to justify it. One manager tells of being persuaded to invest corporate funds in new technology under the Advanced Launch System program, only to have the investment written off when that program was canceled.[13] Lower-tier firms will invest in new technologies that can be used in space transportation systems, but only if there are other—preferably commercial—markets for them.

Several companies say that they have, on the shelf, launch vehicle component technology considerably more advanced than that which is flying in today's space transportation systems. Proposals to incorporate this new technology in space transportation systems are typically not accepted by the customer, because of the additional cost involved or questions of reliability and safety. Some experts point out that such reluctance may be entirely justified, and that new technology infusions need to be carefully incorporated into planned, integrated vehicle upgrades, in order to avoid system engineering problems.[14]

Meanwhile, however, it is becoming increasingly difficult and costly for firms to continue to build antiquated designs. Short production runs and long set-up time dictate high-cost production. For example, in order to get one of its suppliers to produce a component for a subsystem used in the Titan launch vehicle, one lower-tier firm had to buy a large quantity of the item, far more than the near-term requirement would justify. Another firm notes that the facilities used to fabricate, assemble, or integrate the existing, antiquated designs are aging and costing more and more to operate; in addition, the people familiar with the designs and specialized production processes are retiring, further complicating production.

9. Managers at the lower-tier firms believe that they (particularly the liquid-fueled propulsion firms and their suppliers) will bear the brunt of any decision to incorporate Russian

[12] For example, lower-tier firms point to the proliferation of support contractors or internal staffs at the prime contractors, whose role is to prepare reports to management or to the government customer, or to generate plans for the work to be done rather than doing the work itself. Funding agencies and their subordinate staffs impose similar "taxes" on R&D funds en route to contractors.

[13] The company was later able to use the component in a non-launch-vehicle program, but this was not anticipated at the time of the initial R&D commitment.

[14] The Air Force says that it will consider new technologies in the EELV program if they promise to lower costs.

or other foreign technology in U.S. space transportation systems.

Lower-tier firms generally believe that they will bear a disproportionate share of the impact of the incorporation of Russian technologies into existing U.S. space transportation systems. Suppliers are particularly concerned, because U.S. prime contractors are being encouraged by the Clinton Administration to use Russian liquid-fueled engines in new and upgraded systems. Several expressed the view that the U.S. Government was permitting foreign policy concerns to take precedence over preservation of a sound domestic launch vehicle industry.

Others noted that the draft DOD policy that applies to these proposals would require suppliers to demonstrate that adequate provision has been made against disruption of the launch schedule, and that production of foreign-designed components will eventually be shifted to the United States. Experts point out, however, that such a shift would result in significantly higher one-time and recurring costs than if the components were produced in Russia, and would necessitate a steep learning curve for the American suppliers, whether they were firms new to the space market or established suppliers obliged to retool for Russian designs.