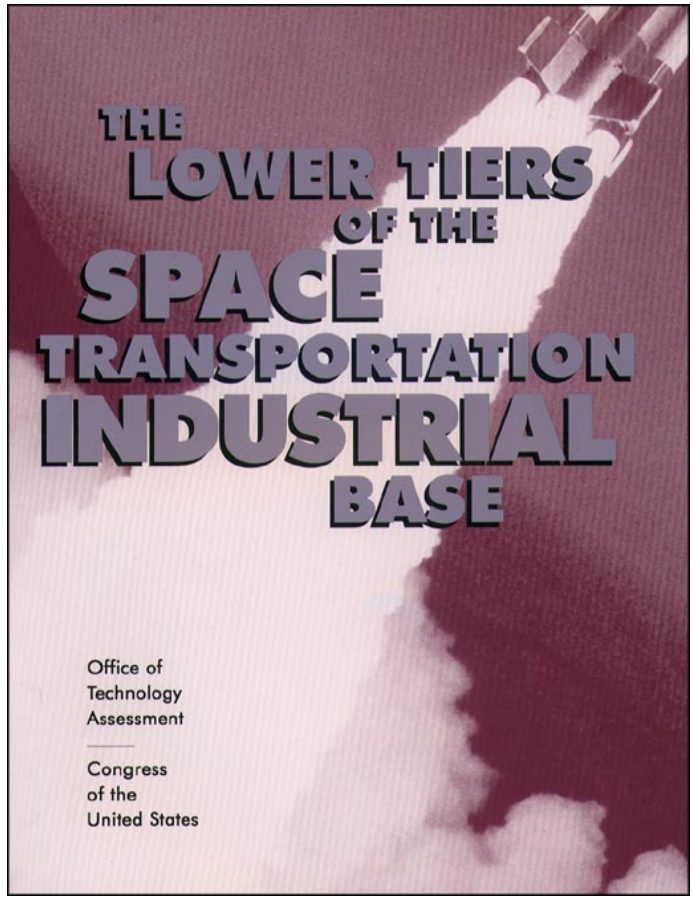
The Lower Tiers of the Space Transportation Industrial Base

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Foreword

Current national space transportation policy, when it considers industry-related questions, is principally directed at, and influenced by, the industry's large prime contractors. Yet the industry is comprised of a much wider variety of firms. The U.S. space transportation industry includes large and small providers of subsystems, components, and materials in areas such as propulsion, avionics, guidance, and structures. For each dollar spent on the procurement of space transportation systems and services, roughly half flows down to second- and lower-tier supplier firms.

This background paper, prepared by the Office of Technology Assessment (OTA) for the House Committee on Science, examines the current status and future prospects of these critical, but often ignored, lower tiers. It is the second product of OTA's assessment of the U.S. space transportation technology and industrial base. It also represents the final OTA report on space technology policy. OTA will close its doors on September 29, 1995.

This background paper was prompted by a workshop held at OTA in early March 1995, at which a small group, representing a broad cross-section of lower-tier firms, discussed their views of the space transportation industry. Participants at the workshop, and other members of the lower tiers contacted subsequently, conveyed profound pessimism about the future. Most participants saw little hope for future expansion in the space transportation business; there was almost uniform skepticism about the government's commitment to build new space transportation systems; and most expressed deep concern about the continuing erosion of human capital and know-how throughout the lower tiers.

The views expressed by the lower-tier firms, however, are not universal. Some prime contractors are more optimistic about the continuing availability of lower-tier capabilities to fill their needs, or of being able to produce needed items in house. One important Department of Defense (DOD) study concluded that the current industrial environment among the lower tiers can be managed by its prime contractors in a manner that will preserve the capabilities of the lower tiers without incurring undue costs or schedule delays. OTA's analysis, both past and present, suggests that this is a valid argument in most cases, but some critical subsystems, components, and materials will require close monitoring. The risk of disrupting government and commercial space missions as a result of interruptions in the supply of critical lower-tier products is real.

In undertaking this effort, OTA sought the contributions of a wide spectrum of knowledgeable individuals and organizations. OTA gratefully acknowledges their contributions of time and intellectual effort. OTA also appreciates the help of both DOD and the National Aeronautics and Space Administration. As with all OTA reports, the content of this background paper is the sole responsibility of OTA and does not necessarily represent the views of our advisors or reviewers.



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Introduction, Background, and Findings

1

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

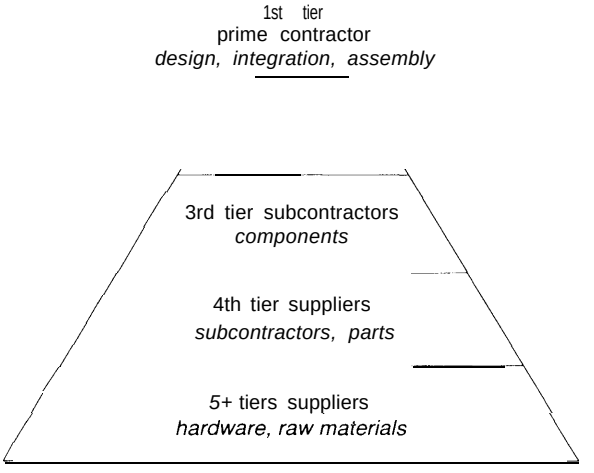
1. **Many of the lower-tier manufacturing firms that supply space transportation system parts, components, and subsystems are not diversified and depend heavily on the launch vehicle, missile, and related military markets. These firms share a pessimistic**

[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.

Characteristics and Observations 2

Since the mid- 1980s and the *Challenger* accident, the nation's space launch capability has been under sharp scrutiny. Studies of the technical options for new launch systems and the demand for space launch services, in particular, have been plentiful.

Without evident exception, however, existing studies have focused virtually their entire attention on the major prime contractors—the relatively few U.S. firms that produce and operate launch vehicles for government and commercial customers. OTA studies of the defense technology and industrial base have noted that focusing on prime contractors alone overlooks a significant fraction of any industry-a fraction that often has very different perspectives from the prime contractors.[2]

THE SIGNIFICANCE OF THE LOWER INDUSTRIAL TIERS

In the space transportation industry, the major first-tier firms or "primes" are responsible for overall assembly, integration, and often operation of U.S.-made space transportation systems. In addition, they are increasingly involved in the fabrication of sys-

"The Earth is covered by two-thirds water and one-third launch studies."

—USAF Secretary S. Widnall[1]

[1] As quoted by Aerospace Industry Association President Don Fuqua, *Military Space,* Dec. *12, 1994,* p. 1.

[2] For example, see U.S. Congress, Office of Technology Assessment, *Assessing the Potential for Civil-Military integration: Technologies, Processes and Practices, OT.4-[SS-6 11* (Washington, DC: U.S. Government Printing Office, September, 1994); *Building Future Security,* OTA-ISC-530 (Washington, DC: U.S. Government Printing Office, June 1992); and *Redesigning Defense: Planning the Transition to the Future U.S. Defense Industrial Base,* OTA-ISC-500 (Washington, DC: U.S. Government Printing Office, July 1991). While these studies addressed the broader topic of the defense technology industrial base, much of the U.S. space launch industry can be regarded as a subcategory of the defense base, and the analysis is generally applicable.

tems, subsystems, and component parts for their vehicles. Rockwell International, Lockheed Martin, McDonnell Douglas, and Orbital Sciences are the only current U.S. builders and operators of proven space launch vehicles; several smaller firms have launch vehicles in various stages of design or development.

The lower tiers of the space transportation industry begin with second-tier subcontractors that manufacture major subsystems and components for incorporation by the primes into space transportation systems. Third-tier firms sell to the second tier, fourth-tier to the third tier, and so on until the level of raw materials is reached. The common distinguishing characteristic of lower-tier firms is that they sell to the first-tier firms, or to other lower-tier firms, rather than directly to the final space transportation customer.

THE NATURE OF LOWER-TIER FIRMS

Lower-tier firms vary greatly in size and organization. Some are entirely or almost entirely dependent on space business, but most are more diversified, if only within the government marketplace. Some are independent, while others are divisions of larger corporations. Some do most or all of their space business selling to a single prime contractor for a particular launch vehicle series; others sell a narrow range of products to virtually the entire list of primes.[3] Still others have developed a wider range of products drawing on a core firm capability, which they successfully sell to both the primes and other customers. One firm, for example, sells pyrotechnic devices that are widely used on U.S. and European expendable launch vehicles (ELVs), the Space Shuttle, military aircraft, and in most of the world's automotive airbag systems.

Complicating the picture, many lower-tier firms sell products to both primes *and* other lower-tier firms. This is particularly common where the primes have undertaken the assembly or fabrication of items formerly made by subcontractors.

OTA studies of the defense technology and industrial base found that between 40 and 55 percent of defense procurement funds spent for aerospace systems (depending on the specific system involved) are passed on by the prime contractors to their supporting subcontractors and suppliers. An input-output analysis being conducted by OTA in connection with its assessment of the U.S. space transportation industry yields similar conclusions for that industry. That analysis (which is being refined and further validated) appears to demonstrate that between 45 and 50 percent of the value added to U.S. space transportation systems can be attributed to lower-tier firms.

During the OTA workshop discussion, some attempt was made to distinguish between second-tier firms (those that sell directly to the primes) and third-tier or lower companies, which sell in turn to other lower-tier firms. The analytical value of these internal distinctions among lower-tier firms lies chiefly in understanding the extent to which government policies, in the form of regulations, requirements, and oversight directed at the prime contractors, may flow down to lower-tier firms, and how much this flow-down is attenuated as it passes through additional layers.[4] This information is critical to policymakers who may expect their legislation or regulations to govern 100 percent of government outlays for space transportation, when in fact they may not reach far beyond the primes. (See box 2-1 for a summary of current procurement reform activities.)

Below the subcontractors, and occupying the lowest tiers of the industrial base, are the commodity suppliers of parts and materials. Many suppliers in the space transportation industry produce "dual-use" equipment and supplies that are used in both space and non-space applications. As a group, these firms are more diversified than the

[3] Such as range safety receivers used to trigger the destruction of a launch vehicle that strays off-course and threatens populated areas.

[4] OTA has written extensively on the differences between government and commercial procurement. See, in particular, U.S. Congress, Office of Technology Assessment, *Assessing the Potential for Civil-Military Integration*, op. cit., footnote 2.

BOX 2-1: Acquisition Reform

A number of acquisition reform steps have been taken or are currently being contemplated that will affect the purchase of space transportation systems In February 1994, DOD's white paper, Acquisition Reform: A Mandate for Change, outlined its vision of future defense acquisition. This vision Included increased commercial purchases; greater use of commercial specifications and standards, reduced admimstrative burdens on providers of defense goods and services, and the adoption of some commercial business practices by the DOD procurement bureaucracy. In early March, DOD released its first report measuring progress in the acquisition of commercial and non-developmental items.[1] In June 1994, the Secretary of Defense issued a directive changing the use of military specifications and standards [2]

The Federal Acquisition Streamlining Act of 1994 (FASA) was passed in October 1994. FASA incorporates many of the acquisition law reforms proposed by the congressionally mandated Acquisition Law Advisory Panel, which in January 1993 issued a report to Congress on streamlining defense acquisition laws. The Act addresses the purchase of commercial items and services, provides a clearer definition of commercial items and services for use by the contracting community, eliminates the requirement for cost and pricing data on commercial items; and makes it more difficult for the government to demand technical data rights for items developed with private funds

In addition, FASA addresses a number of other reforms that should make it easier for commercial firms to do business with DOD (e g , raises the Simplified Acquisition threshold and reduces the use of unique socioeconomic clauses in certain categories of government contracts).

As this report was being written, Congress was contemplating four additional major acquisition reform bills. These include:

—The DOD Acquisition Management Reform Act (H.R. 1368 and S. 646), sponsored by Rep, John Kasich and Sen. William Roth. This bill rolls the military services' research, development, and acquisition agencies into a central office. It calls for programs to be canceled if they fail to meet performance goals. It stops the Pentagon from reserving 60 percent of maintenance work for military depots.

—The 1996 National Defense Authorization Act (H.R. 1530 and S. 727), sponsored by Rep. Floyd Spence and Sen. Strom Thurmond. This bill is supported by Pentagon officials. It repeals the fee added to foreign military sales that helps recoup U.S. - funded research and development, ends the 60-percent set-aside for military depots, and allows pilot programs to be exempted from regulations.

—The Federal Acquisition Improvement Act (H.R. 1388 and S. 669), sponsored by Rep. William Clinger and Sen. John Glenn. This bill was drafted to apply to the entire government. It allows government contract officers to limit the number of bidders in competitions. Complainants would pay the cost of frivolous bid protests. The bill also precludes protests of competitions staged on the electronic commerce bulletin board the government is setting up.

—The Federal Acquisition Reform Act (H.R. 1670), sponsored by Reps. Floyd Spence and William Clinger. This bill ends the requirement to hold "full and open competitions," going further than the H.R. 1388 /S. 669 provision to limit bidders. It also repeals the recoupment fee on exports, codifies the practice of buying commercial goods and services whenever possible, and relaxes accounting practices for them

[1] R. Noel Longuemore, "Memorandum for Deputy Secretary of Defense Measuring DOD Progress in Acquisition of Commercial and Other Non-Developmental Hems, " Mar 4, 1994

[2] William J. Perry, Secretary of Defense, "Memorandum for the Secretaries of the Military Departments Specifications and Standards—A New Way of Doing Business," June 29, 1994

SOURCE Office of Technology Assessment, 1995

subcontractors, and are more integrated with the commercial market. Firms in this category contacted by OTA were often only vaguely aware (or even unaware) that their products were used in space launch vehicles.

The Limited Space Transportation Market

Perhaps the most significant feature of the space transportation technology and industrial base is the limited market for space transportation systems, compared with commercial and other defense aerospace products.

In 1994, the United States conducted only 27 space launches, of which 7 were flights of the partially reusable Space Shuttle. From 1980 through the end of 1994, the total was 274, of which 66 were Shuttle flights and 208 were ELVs (an average of only 14 new vehicles produced per year).[5] This limited production rate, spread historically across six or more vehicle families, has only a few direct analogues in the military aerospace sector, and creates a significantly different business environment for the lower-tier space transportation firms than what is ordinarily encountered in the defense or commercial marketplaces.

Projections of future demand for ELVs generally portray a slowly growing commercial market, while the launch rate for captive U.S. government payloads is relatively flat or declining somewhat. Moreover, intensifying foreign competition for commercial payloads from Europe's Ariane, Russia's Proton, and China's Long March vehicles has reduced the U.S. share of this market to only 16 out of 66 geosynchronous orbit payloads scheduled for launch over 1995-97 (launch contracts for 17 satellites are still to be awarded).[6] This relatively flat demand for U.S. vehicles will be complemented, beginning in 1996, by launches of the initial constellations of low-Earth-orbit (LEO) communications satellite systems (e.g., Iridium, Globalstar), but the U.S. ability to retain a significant share of this market is also in question.

Who Are The Customers?

Another important feature of the space transportation industry is that the prime contractors serve several customers, each with technical and procedural requirements that often differ significantly. McDonnell Douglas, for example, sells Delta II vehicles or launch services to DOD, NASA, and commercial communications satellite owners.

The governmental customers differ substantially in the way that they approach these procurements, although the degree of difference is a contentious topic between NASA and DOD. In NASA's view, DOD buys launch *vehicles* and launch *services* separately. In addition, NASA's technical and procedural requirements are significantly different from DOD's. NASA states that it is required by law to purchase launch *services* (where a commercial vendor both provides the vehicle and launches it, under a single contract), rather than launch *vehicles*. NASA believes it is effectively precluded for this and other legal reasons from joining in common procurements with DOD.

DOD, on the other hand, says that it also buys launch services, but with special conditions that are dictated by the requirements of national security. DOD asserts that NASA overstates the differences between their practices and the difficulty of joint procurements, and that NASA tends to be more restrictive than DOD in the detailed require-

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[5] ANSER Corporation, *1994 Space Launch Activities* (Aerospace Division note ADN 95-2, Arlington, VA, January, 1995).

[6] U.S. Department of Transportation, Commercial Space Transportation Advisory Committee (COMSTAC), *Commercial Spacecraft Mission Model Update*, May 1995. See particularly Appendix 2: 1995 Mission Model—Near Term. Note that the figures cited reflect spacecraft launched into geosynchronous transfer orbit, rather than launch vehicles; that no small launch vehicles are included; and that slightly less than 50 percent of all Ariane launches involve two spacecraft per launch vehicle. Nevertheless, this model indicates that the U.S. space transportation industry's share of the commercial satellite market has declined to only 5 to 6 medium-to-heavy class launches per year, less than 25 percent of the total.

ments it imposes on its vendors.[7] All government customers are more specific and intrusive than commercial purchasers, who tend to impose few requirements on the prime contractors other than performance on schedule, to specification, and at a certain price.[8]

When the customer's requirements differ, the requirements levied on the lower-tier firms often vary accordingly. Moreover, the primes tend to add their own accounting or oversight requirements on top of those flowed down from their commercial and government customers.

RECENT STUDIES

The two most recent, comprehensive studies of the space launch industrial base are the DOD's January 1995 *Industrial Assessment for Space Launch Vehicles*, and "The Future of the U.S. Space Industrial Base," compiled by the Vice President's Space Policy Advisory Board in November 1992.

The DOD assessment explicitly "focuses on ELVs and the prime contractors that produce them."[9] It concludes that "the U.S. space industry will continue to meet DOD requirements into the foreseeable future," because "existing manufacturers of DOD's space launch vehicles are profitable despite declining sales, increased competition and significant excess capacity in the large and small vehicle segments."[10]

The assessment goes on to foresee substantial industry consolidation, and to anticipate that DOD will benefit, "since consolidation will lead to reduced overhead costs and reduced prices." It notes that DOD's acquisition process gives it more information about subcontractor costs and therefore more leverage over prime contractors than commercial buyers could achieve. It concludes that although the lower tiers of the industry will consolidate, sufficient capable suppliers will remain, and that "the major prime and first-tier contractors have demonstrated an ability to manage the risks associated with a changing vendor base."[11] Finally, it sees no need for changes in procurement policy or DOD's business practices, despite ongoing reform efforts within DOD and the executive branch in general to adopt more commercial business practices.

In 1992, Vice President Quayle's Space Policy Advisory Board's report (hereafter, the Quayle report) took a somewhat less optimistic view of the situation. It opened with the observation that "today, a unique combination of circumstances is adversely affecting the U.S. space industrial base.... [It is]...faced with major uncertainties from each of three business areas: military space, civil space and commercial space."[12]

The Quayle report noted that the space transportation industrial base was affected almost equally by DOD and NASA actions and that, for different reasons, both budgets were under pressure. The report concluded that military space might fare better than other defense sectors, since many of the production systems were not keyed directly to the past Soviet threat. For NASA's part, the report noted that a flat budget and growing operational commitments meant that NASA would be hard pressed to undertake new initiatives in

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[7] For a further discussion of these different views, see box 6 in 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), pp. 44-45.

[8] One reviewer commented that there are also payload-related variations that tend to make each launch vehicle essentially custom-made, whether it is built for NASA, DOD, or a commercial customer.

[9] U.S. Department of Defense, *Industrial Assessment for Space Launch Vehicles* (Washington, DC: Department of Defense, January 1995), p. ES-1.

[10] Ibid., p. ES-8.

[11] Ibid., p. ES-10.

[12] Vice President's Space Policy Advisory Board, "The Future of the U.S. Space Industrial Base: A Task Group Report," November 1992, pp. 23-24.

technology or space systems, which contribute significantly to the competency of the space transportation industrial base.[13]

Turning specifically to the industrial base, the Quayle report described it as "capable, but fragile." Addressing the lower tiers (and focusing mainly on spacecraft rather than launch vehicles), it noted:

> Many aerospace prime contractors are concerned that cutbacks in government procurements or declines in export orders 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. In the space field, some important components such as solar cells, nickel cadmium batteries and control moment gyros have only a few domestic sources.[14]

OTA's analysis of this case, as well as comparison to the situation across the broader 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 government requirements that limit their flexibility unduly. However, prime contractors cannot be expected to take preventive steps to maintain lower-tier capabilities unless they can expect to profit from doing so. For this reason, the risk is real that interruptions in the supply of critical lower-tier products could disrupt important DOD and NASA missions.

IMPLICATIONS OF FUTURE VEHICLE CHOICES

Current NASA and DOD development plans include three principal programs under the overall rubric of the National Space Transportation Policy:

- The X-33, a sub-scale advanced technology demonstrator. It will be, at a minimum, an autonomous, suborbital, experimental precursor to a commercial, single-stage-to-orbit, reusable launch vehicle (RLV) in the medium-to-heavy payload class.
- The X-34, a partially reusable demonstration vehicle for small LEO payloads.
- The Evolved Expendable Launch Vehicle (EELV), a new, single family of medium and heavy launch vehicles based on an evolutionary redesign of one or more existing ELVs.[15]

All three systems are being designed to reduce space transportation costs, with the greatest cost reductions planned for the RLV systems.

Many lower-tier firms, particularly those involved in production of ELV subsystems or components, are skeptical that partially or fully reusable systems will replace ELVs for all applications. In any case, their economic survival depends on the correctness of this judgment; for example, manufacturers of large solid rocket motors and their suppliers are concerned that the X-33 concepts discussed so far exclude the use of large solid rocket motors.[16] Conversely, some firms that have developed competencies in systems and subsystems used in aircraft or in the Space Shuttle see the reusable systems as more in

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[13] Ibid., p. 24. This prediction was made well before recent major cutbacks in NASA's budget.

[14] Ibid., p. 25.

[15] See U.S. Congress, Office of Technology Assessment, *The National Space Transportation Policy: Issues for Congress*, May 1995, op. cit., footnote 7. In addition, NASA is planning a modest series of flight tests using a modification of the McDonnell Douglas DC-X, called the DC-XA, and may pursue major block upgrades to the Space Shuttle beginning in 2000, if the X-33 program does not look as if it will lead to a commercial RLV.

[16] A LEO RLV could be designed to accept solid rocket motor strap-ons to boost its orbit or increase its payload capacity.

their interest, although they typically point out that once a few reusable systems (perhaps five, initially) are built, their role would be reduced to maintenance or the supply of spare parts.

In addition to these proposed governmental initiatives, several private-sector efforts could affect the prospects of the lower-tier firms. These include:

- McDonnell Douglas' initiative to develop a Delta III launch vehicle to compete with Atlas, Ariane, Long March, and Proton.
- Efforts by Lockheed Martin and Orbital Sciences, in particular, to respond to a projected demand for increasing numbers of small launch vehicles.

On May 10, 1995, McDonnell Douglas announced that it intends to develop the Delta III, a medium-heavy ELV capable of placing up to 8,400 pounds in geosynchronous transfer orbit. It made this decision on the strength of a contract with Hughes Space and Communications International for 10 firm launches of Hughes' largest satellite, the HS601, plus 10 or more additional launches. The first 10 launches would take place from 1998 through 2002, with optional launches continuing through 2005. The total value of the contract, depending on options exercised, could be up to $1.5 billion.[17]

The Delta III development could result in an improvement in the U.S. market share in its launch class, to the extent that it wins orders that would otherwise have gone to Ariane, Long March, or Proton. But it could also undermine Atlas' market share, a prospect that may partly explain Lockheed Martin's decision to form a new marketing arrangement to market the Atlas and Proton vehicles jointly. Hence, the Delta III's entry into the market appears likely to result in a small to moderate expansion in the demand for the products of the U.S. lower-tier firms.

The chief commercial application for small launch vehicles, such as Lockheed Martin's LLV and Orbital Sciences' Pegasus and Taurus, will be the launch of LEO communications satellites. In its latest projections of the demand for LEO launch services, the Department of Transportation's Commercial Space Transportation Advisory Committee estimates small launch vehicle demand at 4 launches in 1995, growing to 9 to 14 per year from 1996 through 2005.[18]

The Advisory Committee projects that demand for medium-to-large launch vehicles from this source will equal 5 to 10 per year during 1996-1998, from 0 to 6 per year in the years 1999-2001, 6 to 9 per year in 2002-2003, and 4 to 6 per year in 2004-2005.

Attainment of these levels of demand for either size class of launch vehicle depends on realization of scenarios involving the operational deployment of two to three "Big LEO" satellite systems, such as Motorola's Iridium, and one to two "Little LEO" systems, such as Orbital Sciences' Orbcomm.[19] It is not yet clear, however, whether these expectations will materialize. Projections of launch demand resulting from new satellite services have sometimes been severely overstated.[20]

Increased demand for small launch vehicles (a field in which the United States, at this time, is in a dominant position) could be a positive development for the industry, including the lower-tier

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[17] McDonnell Douglas Aerospace press release, May 10, 1995; Hughes Space and Communications International press release, May 10, 1995.

[18] U.S. Department of Transportation, Commercial Space Transportation Advisory Committee, "LEO Commercial Market Projections," May 1995.

[19] The distinction between the two lies in their capabilities and, secondarily, the size of the satellites used. For purposes of this study, the significance is that "Little LEO" systems will rely largely on small launch vehicles for both initial deployment and the launch of replacement satellites, while "Big LEO" satellites are to be launched initially on medium-heavy launch vehicles, with only replacements carried on the smaller vehicles.

[20] For example, inflated expectations for the launch of large numbers of direct TV broadcast satellites in the mid-to-late 1980s seriously distorted estimates of launch vehicle demand at that time.

firms. On the other hand, these vehicles are relatively cheap and simple; the per-vehicle return to the lower-tier firms is thus relatively low compared with larger vehicles.

Growth in demand for small launch vehicles, most of which use solid rocket motors, could also help maintain the industrial base for the production of long-range ballistic missiles, through sustaining demand for large solid rocket motors and expertise in their application to complete systems. To the extent that the LEO market for medium-to-large ELVs does indeed develop, it could further strengthen the business base for lower-tier firms. As mentioned in chapter 1, however, commercially viable RLVs could significantly alter future demand for ELVs.

SINGLE SOURCES AND SOLE SOURCES—HOW VULNERABLE?

One response to competitive pressures and declining markets on the part of the primes has been to seek cost savings through greater vertical integration (bringing work in house that formerly was done by subcontractors or suppliers) or through reducing the number of outside suppliers of a given subsystem or component part. In this respect, their behavior is no different than that of much of U.S. business in recent years. An important question, however, is whether these trends adversely affect the sustainability of lower-tier capabilities in the U.S. space transportation industry, given the high-cost, low-volume, specialized character of the business.

The authors of the DOD's *Industrial Assessment for Space Launch Vehicles* see no correlation between a reduced number of lower-tier suppliers and loss of industrial capabilities. They believe that consolidation and extensive use of single sources is a natural course of action for U.S. aerospace companies, given the high cost of qualifying products for space applications. They point out that the U.S. national interest lies not in the preservation of particular companies, but rather of essential capabilities. They predict fewer lower-tier firms (as well as prime contractors), but do not foresee loss of essential capabilities among the lower-tier firms, and expect to address any problems that develop on a case-by-case basis.[21]

Others, including a majority of lower-tier firms contacted and some government officials familiar with the space transportation industry, are not so optimistic. They believe that the combined impact of limited demand for space transportation, skepticism about government intentions, strained relations with prime contractors, increasing foreign competition, the perceived ineffectiveness of procurement reform, and other, psychological factors may cause a number of key firms to leave the space transportation market altogether, and will deter new firms from entering that market.

They also believe that the sharp decline in entry of new engineers and scientists into the space transportation industry, coupled with the laying-off or retirement of many experienced, senior personnel, is leading to a weakening of the sector's overall capabilities. Finally, they note the vulnerability of some key lower-tier firms to external forces, such as environmental regulations that could challenge their ability to stay in business.[22]

OTA agrees with DOD that a reduction in the number of suppliers, by itself, is not inherently worrying. Indeed, a shakeout resulting in fewer suppliers, each receiving a larger share of the available business, might be a healthy adaptation to the post-Cold War environment.[23] However, there is a legitimate concern that the shakeout will go too far, and that the primes will encounter inordinate delays and high costs related to qualifying new firms or facilities to replace suppliers who have left the marketplace.

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[21] U.S. Department of Defense, personal communication, June 1995.

[22] Producers of solid-propellant rocket motors appear to be particularly vulnerable to environmental regulatory pressures.

[23] U.S. Congress, Office of Technology Assessment, *Building Future Security*, op. cit., footnote 2, pp. 90-91.

Workshop Highlights 3

OTA's workshop on the lower industrial tiers of the space transportation industry was held on March 2, 1995. Workshop participants are listed in the front of this report. Unlike chapters 1 and 2, this chapter reflects only the discussion at the workshop.

The complement of firms represented was fairly diverse. It included seven manufacturing and three service firms, ranging in size from a few millions of dollars in annual sales to over a half–billion. Firms were selected from a cross section of the industry, including avionics, propulsion, structures, materials, instrumentation, and fuels. And they were selected for their work on the full–range of current space launch vehicles and long–range ballistic missiles, as well as many retired systems. The firms characterized themselves as occupying predominantly the second and third tiers.[1]

CURRENT STATUS AND CRITICAL SECTORS

The single most striking characteristic of the discussion at the workshop was the general pessimism of the participants, based on the view that the defense and space markets were shrinking and that this trend was unlikely to reverse itself.

One participant said that his firm has dwindled from 500 employees to 240 over the last three years, and is having difficulty getting its suppliers to build the obsolete components that are re-

"... the United States has not yet adequate/y defined its goals in the space launch field.. ."

[1] According to preliminary input–output analysis, OTA estimates that the second and third tiers account for more than 35 percent of the value added in space transportation systems. OTA conducted telephone interviews with representatives of the fourth and lower tiers, which account for less than 10 percent of value added, to augment the discussion in chapters 1 and 2.

quired to support existing launch vehicle designs, because of *their* pessimism about the future of the market.

Another agreed, and said that as a result, his firm's facilities are obsolete and the know–how to maintain and operate them is dissipating as retirements and downsizing continue. He reflected skepticism that current launch vehicle development studies would result in anything being built, and emphasized that preservation of the industry's skill base could not be achieved by studies, but only by the actual construction of new or evolved launch vehicles.

Another participant said that his firm would be closing its plant for the manufacture of large solid rocket motor nozzles at the end of March 1995, because its business base had evaporated. The result, he said, would be to leave only one surviving firm in his market niche.

Another participant described his firm as heavily diversified, with as much sales volume in the non–aerospace market as in aerospace. He described the company's military and other government business as shrinking rapidly, and its remaining base primarily in the aircraft field rather than the missile and space business.

When asked to identify elements of the lower–tier industrial base that are being particularly hard hit, one participant said that solid propulsion is especially vulnerable. Makers of long–range ballistic missiles and tactical missiles have little work. If that trend continues, they will become increasingly dependent on their related launch vehicle business both for work and for maintaining critical missile capabilities.[2]

Solid rocket motors are currently used in several expendable launch vehicles or ELVs (e.g., Delta, Titan, Lockheed Launch Vehicle, and Taurus), and are a major component of the Space Shuttle. The Lockheed Launch Vehicle and the Taurus use a motor derived from the Peacekeeper intercontinental ballistic missile. DOD and NASA space transportation development plans, however, could all but eliminate the need for solid rocket propulsion in launch vehicles, if the Evolved Expendable Launch Vehicle (EELV) program and reusable launch vehicle (RLV) programs are successful and rely exclusively on liquid–fueled engines.[3]

Continuing on this theme, one participant noted that some firms producing inputs to the solid rocket business are also leaving the business. For example, he said, there is only one maker of rayon for carbon–carbon composite structures. Aerospace forgings are almost impossible to get now in any size, he continued. There are only a handful of shops in the country big enough to handle the equipment, and some of them are leaving the aerospace business.

As for restarting a program after a hiatus, he said, once a plant closes, its specialized facilities are lost to the industry. In his view, it is almost too late to reverse the trend. NASA's current proposal for the X–33 RLV foresees a delay of 4 to 5 years before serious production can begin on anything beyond the initial demonstration vehicle, and many subcontractors will be out of the business by that time.

One of the most serious problems faced by lower–tier companies is the loss of experienced people and a lack of hiring of young engineers and technicians. All the firms that commented on this issue said that they have not hired anyone in several years. Young engineers are staying away from aerospace, they said, because of its declining employment and uncertain future. One mentioned that his firm had previously drawn on a pool of young engineers who came to the firm under

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[2] All current U.S. long–range ballistic missiles have solid rocket motors. If solid rocket motor capabilities were lost, the government could conceivably design new weapon systems based on new RLV technology and liquid–fueled engines. This possibility is not now being seriously considered.

[3] 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).

work–study programs, but that the firm had stopped using these "co–ops" several years ago.

In general, participants said that fewer than half of the people in their companies involved in launch vehicles five years ago are still in the field. In time, they predicted, even though some firms might survive, they would not have retained the pool of skills unique to the industry (such as designing for the special requirements of operating in the vacuum of space), because work and training will not have continued.

Participants also commented on the dearth of investment in launch vehicle–related industrial facilities. They asserted that there has been little or no investment over the past 25 to 30 years. Materials and fabrication techniques have not been changed, they said, and space technology in some areas, such as advanced composites, is "Stone Age."

Participants identified environmental regulations as a major brake on doing business. They felt that stringent application of environmental controls was significantly raising their costs and complicating their operations. In this regard, they cited the phasing–out of ozone–depleting chemicals, Superfund–related litigation and cleanup costs, and overly stringent water–quality requirements on manufacturing facilities.

One participant noted that even though water entering his facility was more contaminated than when it left, his firm was obligated to make its runoff meet Clean Water Act standards as if the supply water had been pure to begin with.

Another participant mentioned that lower–tier firms in Southern California are finding themselves unable to obtain working capital, even with firm contracts in hand, because banks avoid funding anything in the aerospace field. Others had heard of similar cases in other parts of the country, and speculated that banks fear that any government aerospace contracts are imminently vulnerable to alteration or cancellation.

Finally, one participant cited an ongoing Air Force study that he said appears to conclude, on the basis of limited data, that 35 to 40 percent of the lower–tier firms in the space industry will cease doing government–related business within the next five years. He believes there would probably still be sources for the items that the lower–tier firms had provided, but said that the impact on the lower tiers would be far greater than on the primes. The primes, he said, would find other business to do or consolidate, but they would not go out of business.

THE IMPACT OF FUTURE VEHICLE CHOICES

Most participants expressed skepticism about the proposed EELV and X–33 RLV programs. Several strongly doubted that there was a commitment in the government to build a new vehicle after so many false starts. One argued that the EELV program was likely to be carried through, but others commented that at best the EELV program was more likely to result in an upgraded Delta or Atlas than a new family of vehicles.

Another participant said that while a follow–on RLV derived from the X–33 demonstrator would clearly be a new vehicle, he foresaw a repetition of the Space Shuttle experience, with cost growth undermining any hoped–for savings. He further doubted that the funding could be found for the level of effort required. Noting that the government was seeking substantial corporate investment in the program, he said that the prime contractors were skeptical too, and that the lower–tier firms had been burned too often. Some participants expressed concern that the EELV and X–33 RLV programs were not sized to meet the needs of the commercial market and the smaller, cheaper spacecraft that both DOD and NASA are emphasizing.

Commenting on NASA's stated plans to decide in 2000 whether to pursue a next–generation RLV or invest in refurbishing the Space Shuttle, several participants agreed that it would probably be cheaper to build a new RLV than to redesign or rebuild the current Shuttle fleet. Some doubted that NASA considers extending the life of the Shuttle to be a serious option, while others believed that the most likely outcome of developing the EELV and RLV in parallel would be a decision not to pursue the RLV, and to upgrade the Shuttle instead.

Two participants in the workshop noted that they had been approached by prime contractors to join teams bidding on the X–33 program, but that the primes had been seeking significant advance payments from subcontractors wishing to join their team. Their firms had refused to contribute, these participants said, and so other firms were chosen for those teams. Their reluctance was not due to a lack of capital, but because they did not foresee any future market. They said that their firms had contributed willingly to new project teams in the commercial aircraft industry, where they saw the future business potential.

If the X–33 RLV demonstrator succeeds and a decision is made to go forward with a full–scale RLV, some firms at the workshop believed they would benefit because of the "airplane–like" nature of many of its systems. Those firms primarily associated with ELVs saw no relevance to their future prospects, which are closely tied to the future of the EELV program.

One participant noted that although any benefit to his firm from the Space Shuttle program was far in the past, a large share of the NASA budget continued to go to that program, rather than to supporting the industrial base. He predicted that a future RLV would follow a similar pattern, resulting in a limited amount of initial business for the lower–tier firms, followed by years of little or no return while the money flowed into operations.

RELATIONS WITH THE GOVERNMENT, PRIMES, AND MAJOR SUBCONTRACTORS

Relations with both the prime contractors and the government are a major concern for workshop participants. One flatly described the prime contractors as his firm's main competitors, because of their tendency toward greater vertical integration. Others agreed, adding that the accounting systems of the primes tended to obscure the true cost of substituting in–house manufacturing for subcontracting.

For example, one described a situation in which his firm lost a contract after producing a few units because the prime wished to produce the units in house, and could make doing so appear less expensive by not including overhead in the cost figure. Two others noted experiences in which primes first took work in house, then re–dispersed it to subcontractors once it became clear that in–house production was not economical. Another pointed out that because subcontractors were downsizing and losing skilled personnel, prime contractors increasingly risked having no alternative to doing the work themselves, even if they lacked the subcontractors' past experience and ability to do it well.

Several of the participants complained about being asked by prime contractors to contribute to front–end costs as a condition of teaming on new business. One said that since his firm had diversified, and its launch business was no longer a large–enough share of the total, the company would not invest in this way. He predicted that this practice would cause some of the most–skilled lower–tier firms, subcontractors that had built quality products since the 1950s, to disengage from the space market, forcing the primes to build complete systems more and more in house or to resort to new, inexperienced subcontractors.[4]

Another participant commented on the potential difficulties brought on by consolidation among the prime contractors, increasingly obliging lower–tier firms to deal with only one or two potential customers. He said that the prime contractors were applying intense pressure to the lower–tier firms to reduce costs. He emphasized the difficulty that both prime contractors and lower–tier firms—accustomed to working with government requirements—would have in adapting to the commercial marketplace.

[4] A reliance on so–called "build–to–print" companies, in particular, can in the long–run be a false economy, if full–service subcontractors with design capabilities are driven from the market. See *Building Future Security,* OTA–ISC–530 (Washington, DC: U.S. Government Printing Office, June 1992), p. 94.

Turning to the government, one participant said that he believed that the government procurement culture and its counterpart, the corporate culture accustomed to doing business with the government, together represented the biggest obstacle to sustaining the lower tiers of the space launch vehicle industry.[5]

All participants were strongly critical of government procurement practices, and frustrated by the dissonance between claims of substantial reforms and the requests for proposal to which they, through the prime contractor, had to respond.

They felt strongly that the effects of procurement reforms are not being felt at the lower tiers. All complained about the cost and complexity of conforming with government accounting and technical oversight requirements. One participant argued that firms might be dissuaded from entering the commercial market place or implementing cost–saving methods for that market, because of government "lowest–price" requirements that would oblige them to reduce their prices to the government if they offered their goods or services on the commercial market at less than the government contract price.

There was some debate about the behavior of the prime contractors in the area of requirements. Most participants felt that prime contractor behavior tended to mimic or even reinforce the government's intrusive controls and inspections. At least one participant disagreed, arguing that some prime contractors (those with both commercial and government business) are capable of significantly greater flexibility and commercial behavior when not under government procurement strictures.

One participant felt that the government's application of the Commercial Space Launch Act[6] could inadvertently pose a severe competitive threat to his firm. On the one hand, he complained that the government was making too much use of dedicated payload processing facilities, in lieu of those commercially available. On the other, as the government downsizes, he foresaw the possibility of a government decision to privatize these payload processing facilities at minimal cost, in effect setting up a competitor who would not have to invest substantially in order to enter the market.

Another felt that particularly in the area of program support and software development, the government was already a strong competitor, taking business from the lower–tier firms. Since the government was also downsizing, and beginning to cut deeply into its infrastructure, he believed that the same forces leading to more vertical integration by the primes—the desire to protect their employment and skill bases—would also lead the government to pull more of the lower–tier work in house (e.g., into the defense, energy, and NASA laboratories and centers).

RESEARCH AND DEVELOPMENT

There was a general consensus that lower–tier companies were not spending on R&D unique to launch vehicles, because of a lack of confidence in the future of that market. One participant said that his firm ceased such expenditures three years ago. Instead, he said the firm is spending for R&D in areas with future business potential. Another firm would only be willing to spend on R&D related to launch vehicles if the resulting technology would have a direct, specific application to its much larger, more stable commercial aircraft business.

One participant said that the underlying problem remained the lack of confidence in the government's committing enough resources to build a new launch vehicle. Another said his firm did only very narrow, focused R&D with immediate application to its products, and could not afford to do

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[5] For a complete discussion of these issues see U.S. Congress, Office of Technology Assessment, *Assessing the Potential for Civil–Military Integration: Technologies, Processes and Practices*, OTA–ISS–611 (Washington, DC: U.S. Government Printing Office, September, 1994)

[6] The Act was designed to facilitate the transfer of government–owned launch vehicle components, equipment, tooling, and ground facilities to the private sector. It was subsequently repealed and recodified as 49 U.S.C., Subtitle IX.

any related to launch vehicles. Still another commented that technology available off the shelf in his company is so far ahead of that used in current ELVs that there is no real need for additional R&D to support space transportation needs at this time.

Others observed that another disincentive to doing self–funded R&D was the risk that the primes would secure the rights to the resulting technologies and apply them to other programs, from which the developers would receive no residual benefit.

Several participants said government funding is fundamentally ineffective in stimulating or supporting R&D among lower–tier firms. They agreed that such funding is almost always absorbed by the prime contractors, so little reaches lower–tier firms.

One cited work done for the Advanced Launch System, entirely on his firm's own account; none of the program's funding filtered down to the subcontractors. Another commented that prime contractors typically negotiate cost–plus development contracts with the government, but try to persuade their suppliers to take on fixed–price development tasks. Participants generally agreed that many lower–tier firms are not willing to take such risks, given their bad experience with earlier, abortive launch vehicle programs.

Generally, participants felt that most lower–tier firms got little benefit from various mechanisms established by the government to assist industry R&D, such as Cooperative Research and Development Agreements or the Advanced Technology Program. They noted that doing non–product–related R&D for the government was not usually attractive to lower–tier companies, because of potential difficulties establishing subsequent technical data rights.[7] Participants doubted that OTA would find many lower–tier companies wanting to do R&D for its own sake.

There was particular dissatisfaction about working with NASA field centers and Department of Energy national laboratories on technology development projects. One participant said that projects done at NASA's Lewis Research Center, for example, which seemed to be targeted at specific problems in Shuttle design, were never incorporated in the vehicle. Another said that he believed many technology projects at laboratories were make–work. He found it hard to understand why companies should want to be involved in such activities. Still another spoke of finding his company in actual competition for focused R&D contracts with the in–house workforce at a national laboratory.

GLOBAL COMPETITION AND COOPERATION

Participants generally agreed on the need to ensure launch capability for national security missions, but disagreed about whether this required government intervention to ensure the survival of any company or group of companies.

One participant was concerned about the potential for the emergence of a single U.S. launch company, while others questioned if even one needed to survive. One mentioned the possibility of stockpiling either U.S.– or foreign–produced launch vehicles to serve defense needs, in lieu of trying to maintain production capability.

Participants agreed, however, that at best, the government was focusing on the primes, and that little attention was being given to the impact of foreign competition on the lower tiers. One participant believed that neither DOD nor NASA would intervene to save a particular company. All agreed that restoring a launch vehicle production capability after permitting a hiatus would be very expensive and difficult, and that allowing foreign firms control of the launch market would potentially lead to higher launch costs for U.S. satellite manufacturers and eventually to the erosion of the U.S. lead position in satellite manufacturing and services.

Several of the firms represented in the workshop sell limited amounts of equipment to foreign

[7] Small subcontractors also often lack the manpower and legal expertise to compete for government R&D programs.

launch vehicle programs, but all agreed that such business is minor compared to what could be expected if a new U.S. program or programs got underway.

PRESERVATION OF THE TECHNOLOGY AND INDUSTRIAL BASE

Participants in the workshop felt that the United States has not yet adequately defined its goals in the space launch field, and that reaching a consensus on these goals was a fundamental precondition to specific measures to preserve the space transportation technology and industrial base.

Participants generally agreed that if the President and Congress wished to preserve the U.S. space transportation industry, including its lower tiers, it should make a real, long–term commitment to development of at least one new launch vehicle. Most believed that no single system, whether expendable or reusable, could meet all probable requirements. All participants agreed that there was no substitute for a real development program to revive the lower–tier firms, and that only with confidence in the long–term intentions of the Congress would companies be willing to take the risks and make the long–term investments required to keep the U.S. space transportation industry viable.

Participants largely agreed on the need for the government to do more to safeguard and stimulate the technology base. Several participants strongly advocated earmarking focused (as opposed to basic) R&D funding exclusively for the private sector, instead of allowing the national laboratories to compete for it. They also urged streamlining the government's R&D management processes, so that more of the funding would actually go to do the research, and less to oversight and management. Finally, they emphasized the need for structural reform to ensure that R&D funding would flow down past the prime contractor level, and that the benefits of procurement reforms would be felt by lower–tier firms.