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.