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National Security Space Launch Report

The Congressionally Mandated National Security Space Launch Requirements Panel

Prepared for the Office of the Secretary of Defense

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Executive Summary

Introduction

On January 20, 2004, Congress in House Resolution 4200 directed the Secretary of Defense to establish a panel of experts with extensive space launch and operations background to address the future National Security Space (NSS) launch requirements and the means of meeting those requirements. The Department of Defense (DoD) selected the RAND Corporation to facilitate and support this panel in its deliberations between May 2005 and May 2006.

After a comprehensive review and assessment of the future NSS launch requirements, the National Security Space Launch Requirements Panel concluded that the Evolved Expendable Launch Vehicle (EELV) program can satisfy all known and projected NSS requirements through 2020.

The yearlong fact finding and analysis (between May 2005 and May 2006) of this Panel derived many findings on NSS requirements and the means of satisfying them. We introduce them here. A more complete account of the Panel's findings and judgments is found in the body of this report, and, accordingly, a study of the entire document is recommended.

The National Space Transportation Policy (NSTP) of 2004 is clear in declaring reliable and affordable launch "a fundamental goal of the U.S. space program." Given the national security reliance on space services, that is an unarguable position and one that served to guide the Panel throughout the study.

The Panel work commenced with a review of known and potential scientific developments that might lead to fielding a radical breakthrough in space launch during the next 15 years. We uncovered no evidence that such a breakthrough would emerge before 2020. The basic rocketry principles, use of chemically derived thrust, and multiple expendable stages seem certain to remain the design of choice for operational space launch vehicles in the years covered by this study.

Background

Any consideration of future NSS launch requirements must begin with at least a partial description of key decisions and events that led to the existing policy environment. Since the commencement of the space age 50 years ago, the U.S. government has relied on robust launch capabilities to support crucial defense and intelligence missions. These launchers have been key technology enablers underpinning virtually all space activities. Preserving our ability to provide assured space services is critical to maintaining U.S. national security.

By the end of the Apollo era, the U.S. government recognized that the cost of reaching space was so high that it threatened the nation's ability to take full advantage of its space technology and proven capabilities. The National Aeronautics and Space Administration (NASA) was authorized to address this economic challenge by building a National Space Transportation System (now known as the Space Shuttle), which was intended to reduce costs and improve reliability by employing a largely reusable vehicle that would serve as a launch vehicle, spacecraft, and earth recovery system. From the inception of the Shuttle program, it was recognized that high traffic volume would be necessary to enable reducing the cost of access to space. Accordingly, the U.S. government directed that all U.S. payloads, including national security payloads, be launched with the Shuttle and that the existing fleet of Expendable Launch Vehicles (ELVs) be retired. Following the *Challenger* accident in 1986, the U.S. government established a policy that national security payloads would not be dependent on the status of a single-launch vehicle. As a result, the U.S. government relied on existing ELV families with complementary launch capabilities. These legacy systems became the Titan IV, Atlas II, Delta II, and several small vehicles in the Titan II and Pegasus classes.

Widespread concerns about the high cost of Titan IV operations led to initiation of the EELV program in the early 1990s.[1] In August 1994, in recognition of the vital role played by space transportation systems, the Clinton administration issued National Science and Technology Council–4, commonly known as the 1994 NSTP. The directive stated that assuring reliable and affordable access to space was a fundamental goal of the U.S. space program. To this end, the policy mandated that appropriate government agencies work to maintain strong launch systems and infrastructure while modernizing space transportation capabilities and encouraging cost reductions.

The task delegated to DoD was to improve the existing ELV fleet, while NASA was charged with sustaining the Shuttle and developing the technologies necessary for next-generation reusable launch vehicles.

In October 1994, the U.S. Air Force was selected as the executive agency for the newly created EELV program. The objective of the project was to develop a national space launch system capable of reliably satisfying the government's national mission model requirements while reducing space launch costs by at least 25 percent. Under the EELV program's original acquisition strategy, the Air Force would select a single contractor. In November 1997,

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[1] Paul G. Kaminski, Under Secretary of Defense for Acquisition and Technology, "Space Forces Essential to Modern Military," prepared statement to the National Security Subcommittee, House Appropriations Committee, March 23, 1995.

however, a new acquisition approach was adopted because it was determined that a larger than previously envisioned commercial market would support two contractors. The intent was that this new arrangement would create two vehicle families capable of meeting government requirements while also capturing commercial launches, which would result in lower mission costs and higher reliability for all. Consequently, the third phase of the EELV program began in October 1998 when commercial development contracts were awarded to both Boeing and Lockheed Martin. The DoD cost share of the EELV development was $1 billion, split evenly between the two prime contractors. This final phase included engineering and manufacturing of the launch system, launchpads, satellite interfaces, and support infrastructure.

Currently, the EELV program consists of two families of launch vehicles as well as associated launch infrastructure and support systems. Lockheed Martin's Atlas V family is built around a Common Core Booster powered by the Russian-built RD-180 engine; it began operations in August 2002 and has completed eight successful flights with no failures. Boeing's Delta IV family is built around a Common Booster Core powered by the Pratt & Whitney Rocketdyne RS-68 engine; it began operations in November 2002 and has completed six successful launches (although one flight had a correctable anomaly). Both the Atlas V and Delta IV families employ the RL-10 engine for their upper stages. Both vehicles can be launched from Cape Canaveral Air Force Station, Florida, and Vandenberg Air Force Base, California.

In December 2004, the Bush administration issued a new NSTP. The directive adopted the link between assured access to space and the need for two EELV launch families. The document states, "The Secretary of Defense … shall fund the annual fixed costs for both launch service providers until certifying to the President that a capability that reliably provides assured access to space can be maintained without two EELV providers."

In July 2005, in response to the NSTP, NASA Administrator Michael Griffin and Under Secretary of the Air Force Ron Sega reached an agreement[2] regarding the development and use of future launch vehicles. Because of this arrangement, the potential future addressable EELV launch market may include NASA science spacecraft, ISS cargo resupply missions, and commercial satellites. Human exploration missions will not be part of the EELV requirements. (See Appendix B.)

Assessment

From the Panel's first day of deliberations, it has been apparent that the space launch capability inherent in the two EELV families of U.S. rockets (Atlas V and Delta IV) are state-of-the-art technology achievements gained through combined industrial and DoD investment. While these rockets are still comparatively early in their maturation cycle, their performance suggests that they can become workhorse launch vehicles for the future. Both families are supported by modern facilities and capable personnel from manufacturing to launch. Ample evidence

[2] Michael D. Griffin, NASA Administrator, and Ronald M. Sega, DoD Executive Agent for Space, "Space Transportation Strategy," letter to John H. Marburger III, Director, Office of Science and Technology Policy, Executive Office of the President, August 8, 2005. (See Appendix B.)

suggests that these rockets can meet the NSS launch needs of the United States through 2020 (the end of the study period), barring the emergence of payload requirements that exceed their design lift capability. Whatever decisions are taken concerning the future of these rockets, the going-in position should be that they are superior in their current condition and that no managerial actions should be taken in ways that would adversely disturb this known and hard-earned condition.

It is noteworthy that, however capable these rockets, they do not compete on a price basis with those of many foreign launch providers, which all enjoy substantial subsidies and often benefit from skilled labor rates far below those of the United States. Those fiscal realities have made these rockets largely uncompetitive in today's commercial market, and it is unlikely they will capture more than a small number of commercial launch contracts in the future. Therefore, the U.S. government must be prepared to bear virtually the entire financial burden of retaining either or both of these rocket families for the period we evaluated (2005–2020). Further, given that the U.S. government is the only likely customer, the probability that launch demand may drop below a demand that will sustain team proficiency for two families is increased, giving rise to questions of reliability that often stem from low production rates. It also forces contemplation of the inevitable question of whether it is prudent for the U.S. government to underwrite both rocket families over the long term. Determining how many EELV launches the U.S. government will procure each year over the next 15 years is inexact. With the cost and complexity of NSS payloads, the prospect of ever-increasing on-orbit life, increased procurement of commercial space services, and the potential for dual payloads, the ultimate number of NSS launches is far more likely to decrease than to grow.

In addition to evaluating potential commercial launch customers for EELV, the Panel explored other U.S. government users outside the national security realm that might employ the EELV. The possibility exists that NASA could use the EELV to launch unmanned flights to resupply the International Space Station (ISS), perform science missions, and fulfill other space launch requirements. NASA did not select the EELV to fulfill its post-Shuttle human space flight requirements. NASA did, however, agree to use the EELV for civil, science, and ISS cargo resupply missions in the 5- to 20-metric-ton class to the maximum extent possible. The potential for cost savings at the U.S. government level, and the increased reliability due to an expanded launch manifest that would result from NASA's use of the EELV, argues strongly for cooperative launch planning between DoD and NASA.

The NSTP directs that, for the foreseeable future, capabilities developed by the EELV program will be the foundation for U.S. government access to space. It also states that new U.S. commercial space transportation capabilities that demonstrate reliable launch will be allowed to compete for U.S. government missions. The Panel supports inclusion of new entrants but notes a lack of definition concerning how a new development would be selected, or qualified, for inclusion in the manifest. Eliminating the potential for unfounded expectations, both in the U.S. government and by potential offerers, requires timely promulgation of a clear set of technical and programmatic guidelines regarding new commercial entries.

In the late 1990s, those in government and industry had good reason to believe that the combination of U.S. government launch demand and the promise of large numbers of commercial launches would allow the development of two rocket families within the EELV budget, thereby preserving the "assured access to space" policy that was adopted after the *Challenger* accident. The U.S. government invested $1 billion, split evenly between Atlas and Delta developments. The U.S. government anticipated that the two parent companies, Lockheed Martin and Boeing, would also invest heavily in their respective EELV development, which they did. These costly and complex developments, which the U.S. government is now the beneficiary of, were driven in large part by the two companies' desire to be positioned to profit from the expected large launch service buys, driven mainly by commercial demand. The dramatic collapse of the commercial launch demand in the late 1990s and early 2000s, however, left these two EELV families vying for few commercial launches at the same time the number of U.S. government launches was diminishing. The U.S. government intervened to preserve program integrity and to transition from its initial reliance on firm-fixed-price contracts for commercial products to a traditional contract far more suited to the procurement of specialized government products and services. The NSTP directed the Secretary of Defense to fund the annual fixed costs of both contractors until such time that it can be a certified that assured access to space can be maintained without two EELV families. Accordingly, a new contract for EELV launches, called "Buy 3," will cover missions scheduled to launch between 2008 and 2012. Both the cost-plus launch capabilities contracts and the firm-fixed-price launch services contracts are planned to begin between April and June 2006.

The defining concept currently underpinning the dual-family EELV is the need for assured access to space. The essence of the EELV operational concept is to provide high assurance of NSS launch services to payloads deployed on a well-defined "launch-on-schedule" plan. This is in contrast to the Operationally Responsive Space (ORS) concept, which is based on "launch on demand" as determined by largely unplanned operational needs of the end user.

The reliance of the United States on space services to meet national security needs argues strenuously for capable and reliable launch. The reliability argument has led the United States to retain two EELV families so that one might reasonably be available in the event of a systemic failure in the other. The losses of *Challenger* and *Columbia*, and corresponding long grounding periods of all the Shuttles following those accidents, seem to underscore the need for this diversity. This Panel does not challenge the need for NSS launch surety but notes that the history of modern expendable rockets being truly "out of commission" for extended periods is sparse. In those cases in which the decision was to delay launch for long periods, as happened with the Titan IV in the late 1990s, it was not so much a case of not being able to launch sooner but rather a conscious choice because the luxury of delay existed. Our analysis suggests that extended delays in payload delivery are far more common than delays caused by rocket availability. Indeed, we regularly learn of delays in the projected launch dates for a number of high-visibility NSS payloads, some measured in years. In that environment, it is not proper to describe "assured access" solely in terms of space launch when in fact it is payload availability that almost invariably is the greater determinant. If assured access is to remain the mantra of NSS, then an analysis of all the elements that make up that concept should be conducted, including payload availability and the possibility of flying through failure. Lastly, for the concept of "assured access" derived from the use of multiple rocket families to be credible, virtually all payloads must be capable of rapid configuration for manifest on all NSS launchers. That is not currently the case and is not planned for some critical payloads.

Further related to the issue of assured access, the Panel contemplated the likely long-term reliability of the two rocket families. In addition to their early demonstrations of reliable performance, both families are produced by companies with a long history of building and flying reliable launch vehicles. The nature of these designs and the extensive certification process used by the U.S. government make it unlikely that either would suffer a systemic failure that could not be resolved in a time frame suitable to meet NSS launch needs. The Panel also believes that the normal anomalies detected during early flights will be adequately addressed but will require close tracking.

The Panel was aware of the United Launch Alliance (ULA) proposal throughout its deliberations but took no position because it was projected that a ULA decision would be taken before this report was published. Nevertheless, and as stated earlier, the U.S. government will be virtually the sole user of EELV products and services, and the sole source of funding for this enterprise, giving the U.S. government both the freedom and the obligation to carefully monitor and manage it. The panel understands that current plans require contracting for additional launches scheduled to begin as early as 2010 ("Buy 4"). Therefore, the U.S. government must quickly acquire deep and unfettered insight into the technical and financial records of this enterprise. A comprehensive cost and performance database is essential to making informed decisions relative to the future course of action, which must be made early enough to allow implementation without schedule disruption. A clear view of the cost to own and operate these two families cannot be determined with confidence until the systems have matured and sufficient data are available for evaluation. These concerns led the Panel to conclude that cost of ownership must be considered along with reliability in determining the proper course of action regarding long-term EELV decisions. It is the Panel's view that a decision regarding the path ahead should be taken as soon as sufficient reliability data are amassed and the true costs of ownership are known. To be consistent with the NSTP, a target date of 2010 should be established for implementation of these decisions.

Other major issues that must be dealt with in determining an appropriate course for the EELV program focus on heavy-lift requirements and the use of the Russian-built RD-180 engine on the Atlas V. The Panel recognizes the desirability of maintaining a heavy-lift capability to provide growth margins for future payloads but believes that such requirements warrant revalidation in light of a budget environment that is anticipated to be austere. The paucity of hard heavy-lift requirements, the tenuous nature of projected requirements, and the absence of a heavy-lift variant of the Atlas family make this a key consideration in defining the course ahead. The potential for coproducing the RD-180 engine in the United States exists, but very substantial investment and several years of engineering development remain for that to become a reality. Another issue to be confronted in the years ahead is both families' reliance on the RL-10 upper-stage engine. Each of these is made complex by a combination of existing policy, the need for substantial additional investment, and a desire to enhance diversity in these two families. We include a more detailed discussion of these and related issues in Chapters Three and Four of this report.

The U.S. government has also held discussions with the Space Exploration Technologies Corporation (SpaceX) concerning the potential for procurement of its Falcon rocket family, with the understanding that if its larger versions prove affordable and reliable, then they will be allowed to compete with EELV. The Panel believes that such an approach is consistent with the provisions of the NSTP and that the incremental block "Buy 1, 2, 3" process is an appropriate vehicle for keeping the door open for qualified emerging entrants.

Within DoD, much attention has been given to the concept of ORS as a means of meeting the rapidly emerging space needs of the modern warfighter. Furthermore, the NSTP directs demonstration of an initial capability for operationally responsive access to and use of space to support national security requirements before 2010. The Panel acknowledges the potential benefit of such a capability but found little hard documentation that equated to a verifiable need. It is the position of the Panel that embarking on an extraordinary effort to develop a launch system more responsive than those that already exist would not be cost-effective until needs are clearly stated, operational concepts are defined, and, most importantly, a family of candidate payloads is within view.

The remainder of this decade will be critical to the NSS launch architecture as the two families mature and knowledge is gained that will be vital to EELV decisions. Anticipating that near future, several EELV issues must be addressed now, including the use of Russian hardware, quantifying the need for heavy-lift capability, common reliance on the RL-10 upper-stage booster, the formulation of specific criteria for commercially supplied space launch, and the need for extensive data gathering on the two EELV families. With successful resolution of these and a modest list of additional issues identified in this study, the EELV program should be counted on to be capable of fulfilling the nation's NSS launch needs for the next several decades.

Findings and Recommendations

Finding 1

While the Atlas V and Delta IV families are early in their operational lives, their developmental legacy, introduction of modern manufacturing and avionics, and flight records to date have been successful. The Panel found the technology embedded in these two rocket families to be commendable, with the promise of meeting NSS needs through 2020 and beyond.

The EELV families (with their supporting manufacturing, processing, and launch infrastructure), the current technology base, the current industrial base, and the ranges (with the planned level of funding and improvements) will satisfy the known and projected NSS mission requirements.

Recommendation 1A: The EELV development programs are true successes and are critical to national security. The Air Force must rigorously protect this capability with resources adequate to sustain these programs. Any additional launch developments must be supported with funding separate from EELV.

Recommendation 1B: The Air Force must fund EELV launch and range infrastructure sufficient to implement planned acquisition strategies.

Finding 2

The U.S. government is likely to be virtually the only EELV customer and must be prepared to bear the full cost of ownership. It is unlikely that more than a minimal commercial market will develop for the EELV.

The national launch forecast in the latter years of this study tends toward lower and lower numbers. EELV manufacturing and launch cadre proficiency will benefit from an increase in the number of annual launches. The provisions of the NSTP regarding required U.S. government use of the EELV make clear the goal of employing the EELV for U.S. government needs beyond classic NSS manifests.

Recommendation 2A: The EELV program would benefit from increased government usage. NASA and DoD should rigorously apply the NSTP with a going-in goal of utilizing EELV for NASA ISS resupply and science missions.

Recommendation 2B: The EELV program would benefit from increased commercial launches. The U.S. government should address measures that will aid the EELV to compete in the price-driven commercial launch marketplace.

Finding 3

The Atlas V and Delta IV were developed with substantial private investment to serve a large commercial market as well as U.S. government customers. Accordingly, the U.S. government initially procured these systems on a commercial basis, making insight into their design and development limited compared with programs intended for near-exclusive U.S. government application. With the U.S. government now postured as virtually the sole user of the EELV, with corresponding needs for a comprehensive understanding of the cost and reliability drivers, more thorough insight is required.

Recommendation 3A: The Air Force should immediately commence a thorough evaluation of the designs of the EELV flight hardware and ground processing and launch facilities to identify needed modifications and the costs associated with the total cost of ownership.

Recommendation 3B: The Air Force should immediately initiate the necessary contract changes for data rights and enabling clauses in order to collect the data required to evaluate the performance and ownership costs of each of the EELV families (Atlas V and Delta IV).

Finding 4

The EELV program represents a major management challenge—with or without the advent of ULA. The next few years are critical in gathering the required data on which to base an objective decision regarding the "path ahead" for this critical national resource.

Recommendation 4: The Air Force should identify the extraordinary management actions and senior review processes required to execute the planned EELV program strategy and then ensure that the leadership and properly skilled technical and program management personnel to direct the program are in place. This may involve placing U.S. government personnel within the respective EELV companies (and ULA, as appropriate) to gather the necessary data and insight.

Finding 5

A great deal of attention has been devoted to evaluating how well the EELV families have satisfied their original intent. Nevertheless, after a decade of development, it is more important to determine today's projected requirements than to evaluate how well yesterday's requirements were met. Accordingly, it is appropriate to revalidate the requirements for heavy lift, assured access, and issues regarding the Atlas V's use of Russian-built engines in parallel with the cost and performance assessments described in Recommendations 3A and 3B. These issues are complex and must be addressed in the very near future to allow formulation of a strategy that meets cost, reliability, and operational needs in time to be implemented in the 2010 time frame. This strategy must consider a broad range of options, including (1) retaining both the Atlas V and the Delta IV, (2) selecting the superior launch vehicle, or (3) using an acceptable EELV alternative if such a capability exists.

Recommendation 5A: The Air Force and the National Reconnaissance Office should immediately (a) determine the necessity of an EELV heavy-lift variant, including development of an Atlas V Heavy, and (b) resolve the RD-180 issue, including coproduction, stockpiling, or U.S. development of an RD-180 replacement.

Recommendation 5B: The U.S. government should develop criteria to be applied in soliciting and potentially selecting EELV alternative vehicles. These criteria should be made available to prospective suppliers so as to manage expectations and eliminate perceptions of U.S. government endorsement where none was intended.

Finding 6

The use of the RL-10 as a common component in the upper stage of both the Atlas V and Delta IV has been raised as a potentially troubling source of a single-point failure. A failure that affects the RL-10 will most likely ground both vehicles.

Recommendation 6: Since the RL-10 is common to both EELV families, the Air Force should immediately assess and then implement appropriate product improvements to reduce risk.

Finding 7

Experiments and studies are in progress by the Air Force and the Defense Advanced Research Projects Agency to demonstrate ORS concepts and requirements in accordance with the NSTP. Development of launch system capabilities beyond those available today should proceed at a pace in consonance with the development of requirements, concepts of operations, and operationally useful payloads. Although experiments may be conducted sooner, the current level of the ORS definition makes it likely that initial operational capability (IOC) for any such system will occur post-2015.

Recommendation 7: The U.S. government should continue the ORS experiments and demonstrations. However, ORS full-scale development should not be undertaken until an operational concept, a family of candidate payloads, and launch vehicles and infrastructure are aligned.

Finding 8

No new technology is required to meet NSS launch requirements through 2020, although advancements will surely be incorporated. However, austere budgets that limit technology developments to those required for satisfying immediate requirements pose the threat of shortfalls in launch-related technologies and the industrial base needed to support future system developments.

Recommendation 8: The U.S. government should identify post-2020 NSS requirements so that key technologies and related industrial efforts can be identified and supported.