July 16, 2014

Mr. Daniel L. Dumbacher
Professor of Practice – Aerospace Engineering
Purdue University – West Lafayette, IN

Testimony before the joint

Committee on Commerce, Science and Transportation, and the Committee on Armed Service's Subcommittee on Strategic Forces U.S. Senate

Chairman Nelson, Chairman Udall and Members of today's respective Committees, thank you for the opportunity to discuss the current state of the U.S. launch enterprise on this, the 45th Anniversary of Apollo 11's launch to the Moon.

The United States' ability to achieve, and go beyond, low-Earth orbit is essential for our Nation's defense, commercial, and space exploration enterprises. The U.S. rocket propulsion industry, including solid and liquid propulsion, as well as launch vehicle design, development and operations, is critical to applications such as strategic and tactical systems and serves as our highway to space.

Throughout my 30-year career in the launch vehicle and propulsion business, ranging from my experience with NASA prior to the first Space Shuttle flight, to my efforts in helping to lead NASA's current development efforts of the Space Launch System (SLS) and the Orion crew capsule, I have learned several significant lessons. One key lesson is that leaving the surface of the Earth and attaining orbital velocity at 17,500 miles per hour is a complex system challenge that continues to test the best of American ingenuity. Some of the many factors key to achieving this task are: technical performance, development risk, development cost, operations cost, schedule, industrial base, and yes, even political concerns – all must be assessed with multiple stakeholders. All of these factors must be considered alongside the extremely complex technical interactions and challenges.

From the technical perspective, all systems must work together to achieve orbital velocity. For example, in designing a launch vehicle, the design team must integrate propulsion systems with propellant tanks, structures, launch loads environments, thermal environments, computers and software, and the logistics of getting the many subsystems from suppliers to assembly facilities and launch facilities. All of these factors affect the technical design of a launch vehicle, in addition to the budget and schedule requirements. I'd like to focus my testimony today on launch systems, propulsion systems, and why certain design decisions were made for past and current vehicles.

In assessing design options, there are phases of the launch ascent to orbit where different propulsion systems better serve the needs of a particular launch vehicle, in a particular phase of flight, for a specific mission. For example, in the early phase of a rocket launch, thrust is more important to initially overcome the Earth's gravity than propulsion efficiency. However, as the vehicle progresses to higher altitudes, and climbs out of the Earth's gravity well, propulsion efficiency becomes more important, even as thrust remains an important technical parameter. This is the fundamental reason that Apollo's Saturn V used liquid oxygen and kerosene. It is also the reason the Space Shuttle used solid propulsion for the initial two minutes of flight in parallel with the liquid oxygen/liquid hydrogen Space Shuttle Main Engines (RS-25). The point being that for initial phases of a launch, solid and liquid oxygen/ kerosene systems perform the necessary functions, and liquid oxygen/liquid hydrogen serve the needs better for upper stages and in space stages, appropriate to the mission.

So the question is,Why are different launch systems needed? For example, Why did the Saturn V use liquid oxygen/kerosene, and the Space Shuttle use solid propulsion? Why has NASA chosen the current Space Launch System configuration? Mission requirements drive the process. When NASA was preparing to go to the Moon in the 1960s, it determined that large amounts of thrust (~7.5M lbs. at liftoff) were needed for the first 2.5 minutes of flight, to put the Apollo spacecraft and lunar lander on the surface of the Moon. To meet the mission need, NASA recognized that much development and testing effort of liquid oxygen/kerosene systems was required, and therefore restarted the Air Force's E-1 development from the 1950's as the F-1 program.

In comparison, during development of the Space Shuttle, NASA determined that it had a lower payload delivery requirement and less need for large liquid oxygen/kerosene systems. This decision was certainly influenced, as are most policy decisions, by constrained budgets. This meant building the safest and most capable system possible, based on specific mission requirements, within budget limits. When NASA was developing the Space Shuttle, solid propulsion was being used by the Titan system and other Defense Department strategic systems. Therefore, NASA determined that these solid systems could be scaled up to meet the Shuttle requirements, thus allowing the Agency to take advantage of an existing solid propulsion industrial base to help reduce development and lifecycle cost. The development cost estimates for the Shuttle's solid booster were approximately $1B, (in early 1970 dollars) which was lower than competing liquid propulsion systems. While NASA also recognized that operations costs for the solids would be larger over the life of the Space Shuttle Program, the trade-off was that near-term development costs were more manageable, and near-term budgets were likely more achievable, given that up-front development costs would be less.

Recently, many of the same challenges weighed during the Apollo and Shuttle development eras, were again considered by NASA during the planning and development process for the new Space Launch System. When beginning to design what would become the Space Launch System, NASA looked at many launch configurations, weighing the pros and cons of each. Again, technical performance, challenges associated with limited budgets, the need to launch the first flight as early as possible, and impacts to the propulsion industrial base weighed heavily in NASA's decision making.

Ultimately, for the Space Launch System, NASA determined that using the solid boosters, based on Space Shuttle experience and Constellation / Ares development of the five-segment booster, minimized the up front development costs, reduced the development risks, and most likely would result in a more timely first flight of the Space Launch System. NASA had also demonstrated, over 110 Space Shuttle flights, that solid propulsion issues resulting in the Challenger disaster had been addressed. In addition, NASA chose to utilize over 40 years of investment in large liquid oxygen / liquid hydrogen engines, and 16 available RS-25's from the Space Shuttle Program, to minimize development cost and risk. As NASA proceeds through the Space Launch System evolution from the 70 metric ton (mt) to the 130 mt system, operations costs are an important factor. NASA's plan is to conduct a full and open competition for the booster system development, between solid and liquid systems, for the 130 mt vehicle. This competition will be requirements-driven, with NASA making proposed development and operations costs a key decision criteria in terms of which companies will be ultimately selected to do the work.

Following the Apollo Program, the U.S. Government focused on utilizing solid propulsion systems and liquid oxygen/ liquid hydrogen systems, limiting its hydrocarbon investments. The U.S. aerospace base reacted by focusing its investments in these areas. Major investment decisions made by owners of key propulsion systems affect other users. For example, the RS-68 used today on the Delta IV shares a significant amount of its supply chain with the Shuttle's RS-25, and therefore, increased use of the RS-68 will have the favorable effect of reducing per unit costs on the RS-25. Another example would be the interdependency of the NASA solid propulsion use and supply chain with the U.S. Navy's Strategic Missile D-5 fleet and most Defense tactical systems.

It is clear that cost growth associated with access to space and propulsion is a major threat to the competitive U.S. launch posture. Therefore, it is essential that the U.S. rocket propulsion industry directly and aggressively address launch system costs, working to drive down the cost to develop and operate launch vehicles and propulsion systems.

The question in front of us now, in my opinion, is how do we best utilize this Nation's precious financial resources to address the U.S. launch and propulsion needs? I would submit that focusing our attention on reducing operations costs of propulsion systems will have the most significant, long-term, beneficial outcome for the Nation, thus improving the United States' ability to get to space and assure long term U.S. launch competitiveness. We also need to address concerns of skill atrophy as our current aerospace workforce ages or changes careers. In my opinion, these challenges are best addressed with technology investments directed toward addressing the operations costs, and do not require full development programs. Investments in new manufacturing techniques such as selective laser melting, 3-D printing, and building and testing the hardware developed with these technologies are critical to furthering the technology and retaining the needed skill base. Use of more efficient government / industry management models, designs meant to reduce operations costs, along with the new manufacturing technologies are also needed.

In conclusion, our national competitive spirit and history of ingenuity has proven, and will continue to prove, to be the best tool to reduce costs while maintaining, and even improving, services and products. The United States should build upon its long investment in solid and liquid oxygen/liquid hydrogen propulsion systems, and allow the marketplace to provide viable choices for use by NASA and the Department of Defense. Competition will incentivize industry to develop efficient management models, use the new technologies that will reduce costs, and continue to search for and develop technologies necessary to reduce development and operations costs.

Thank you for allowing me to appear before you today to share my testimony, and I would be happy to take your questions.