NASA Advisory Council Recommendation

Industrial Base
2011-02-04 (EC-03)

Recommendation:
The Council strongly urges that NASA work expeditiously and visibly to ensure that the industrial base supporting engine production and development is sustained and enhanced.

Major Reasons for the Recommendation:
Financial support of this activity has become time critical--especially given the cancellation of the Constellation program and the end of the Shuttle era.

Consequences of No Action on the Recommendation:
Without NASA's attention to this matter, the engine workforce and knowledge base could slowly decline to a point of being unable to develop new leading edge U.S. engine technology.

NASA Response:
NASA concurs with the recommendation. NASA is already working expeditiously and visibly with other Government space acquisition partners within the Department of Defense (DoD) and intelligence community to address space industrial base issues and the Government's future needs and requirements for rocket engine production and development.

As a member of the National Security Space Industrial Base Council (SIBC), which is co-chaired by the Director of the National Reconnaissance Office and the DoD Executive Agent for Space, NASA works diligently with its partners to coordinate its activities. The SIBC, as chartered, identifies and addresses space industrial base issues across the national security, civil, and commercial space sectors. As each department and agency decides its future needs for space launch and other rocket engine needs, the SIBC will be the forum that seeks to coordinate the impact of those decisions on the affected space industrial base related to engine production and development. While NASA is the driver on large segmented solids, it should be noted that NASA has historically not been the driver of overall rocket engine production and development. For additional background, attached is the June 2011 NASA report to Congress, "*Effects of the Transition to the Space Launch System on the Solid and Liquid Rocket Motor Industrial Bases.*"

NASA, along with other departments and agencies, is also working with a Department of Commerce-led survey of the U.S. space industrial base, which will include suppliers of propulsion elements. This year-long interagency effort will culminate next spring with a report to the President on the health of the U.S. space industrial base and related issues. It will also include recommendations for improving the state of the space industry.

Additionally, NASA is leading a cost sensitivity study of solid rocket motors with representatives from the Office of the Secretary of Defense, the Department of the Navy, and the Department of the Air Force. This ongoing study will help assess the technical and business health of the solid rocket motor industrial base to ensure that the Government's requirements can be met at a reasonable cost. The objective of the study is to inform the user communities of the sensitivity of price to future

demand levels. With the joint participation by the Navy and Air Force, the analysis of future costs for larger diameter solid rocket motors will be based on a common range of assumptions.
Lastly, it should be noted that the May 24, 2011, announcement by NASA Administrator Bolden regarding the next transportation system that will carry humans into deep space contained this passage:

> *"In the coming weeks, we will be making further decisions with regard to the transportation architecture. In the meantime, we are refining the SLS [Space Launch System] concept and defining strategy alternatives based on detailed analysis and input from industry through Broad Agency Announcement study contracts. Additionally, the MPCV [Multi-Purpose Crew Vehicle] team is focusing on further development of the Ground Test Article, other development design and development, as well as coming up with an integrated MPCV/SLS plan that will be affordable, sustainable, and realistic."*

NASA recognizes that decisions on the SLS directly affect the propulsion industrial base. NASA requires large and small propulsion systems to safely execute its mission, and the appropriate industrial base is essential for the Agency's mission success.

Report Regarding

Effects of the Transition to the Space Launch System on the Solid and Liquid Rocket Motor Industrial Bases

Pursuant to Section 306(a) of the NASA Authorization Act of 2010 (P.L. 111-267)

June 2011

Enclosure 2

BACKGROUND

NASA has prepared this report regarding the effects of the transition to the Space Launch System (SLS) in response to direction in Section 306(a) of the NASA Authorization Act of 2010 (P.L. 111-267). The specific requirements of this report are provided below.

306(a): REPORT ON EFFECTS OF TRANSITION TO SPACE LAUNCH SYSTEM ON THE SOLID AND LIQUID ROCKET MOTOR INDUSTRIAL BASES.

REQUIRED.—Not later than 120 days after the date of the enactment of this Act, the Administrator shall submit to Congress a report setting forth an assessment, prepared by the Administrator, in consultation with the Secretary of Defense and the Secretary of Commerce, of the effects of the retirement of the Space Shuttle, and of the transition to the Space Launch System developed pursuant to section 302, on the solid rocket motor industrial base and the liquid rocket motor industrial base in the United States.

(b) MATTERS TO BE ADDRESSED.—In preparing the assessment required by subsection (a), the Administrator shall address the following:

(1) The effects of efficiencies and efforts to stream-line the industrial bases referred to in subsection (a) for support of civil, military, and commercial users.

(2) The extent to which the United States is reliant on non-United States systems, including foreign rocket motors and foreign launch vehicles.

(3) Such other matters as the Administrator, in consultation with the Secretary of Defense and the Secretary of Commerce, may consider appropriate.

In preparing this report, NASA worked with the Office of the Under Secretary of Defense for Acquisition, Technology and Logistics Industrial Policy Team in the Department of Defense (DoD), as well as with the National Oceanic and Atmospheric Administration Office of Space Commercialization, and the Bureau of Industry and Security Office of Technology Evaluation of the Department of Commerce (DoC). This report incorporated elements of the Solid Rocket Motor Industrial Base Interim Sustainment Plan delivered to Congress in June 2010 by the Department of Defense. NASA is part of the interagency task force formed by the Department of Defense to develop the Sustainment Plan, and continues to collaborate with other Federal agencies in addressing the challenges affecting the solid and liquid rocket motor industrial bases. The Sustainment Plan, along with the DoC led assessment of the health of the Space Industrial Base tasked in connection with the 2010 U.S. National Space Policy, are among several studies that NASA is actively participating. As a result, this report provides an assessment based on the information collected to date. Some of the results of these collaborative activities will be reflected in subsequent reports to Congress requested in sections 915 through 917 of the National Defense Authorization Act for FY 2011 (P.L. 111-383).

1.0 RETIREMENT OF THE SPACE SHUTTLE AND TRANSITION TO THE SLS

The Space Shuttle has been NASA's primary means for human access to space since 1981 and is scheduled for retirement in 2011. On October 11, 2010, the NASA Authorization Act of 2010 ("the Act") was enacted, which directs the Agency to develop a SLS as a follow-on to the Space Shuttle that can access cis-lunar space and the regions of space beyond LEO in order to enable the United States to participate in global efforts to access and develop this increasingly strategic region. The Act also provides a series of minimum capabilities that the SLS vehicle must achieve:

- The vehicle must be able to initially lift 70-100 tons to LEO, and must be evolvable to 130 tons or more;
- The vehicle must be able to lift a multi-purpose crew vehicle; and
- The vehicle must be capable of serving as a backup system for supplying and supporting cargo and crew delivery requirements for the International Space Station (ISS) in the event such requirements not otherwise met by available commercial or partner-supplied vehicles.

The Act directs NASA to begin development of the SLS vehicle "as soon as practicable after the date of the enactment of" the Act, with the goal of achieving operational capability for the core elements not later than December 31, 2016.

The Act authorizes a total of $6.9 billion for SLS development over a three-year period, with $1.6 billion authorized in FY 2011. The Department of Defense and Full-Year Continuing Appropriations Act, 2011 (PL 112-10) states not less than $1,800,000,000 shall be for the heavy lift launch vehicle system which shall have a lift capability not less than 130 tons and which shall have an upper stage and other core elements developed simultaneously.

In compliance with the Authorization Act, NASA plans to make use of current investments and workforce as appropriate. The Nation's new SLS will leverage these critical capabilities and experience, while being designed with innovation and robustness. In doing so, NASA's evaluation of SLS designs will be based on key drivers such as affordability, partnerships, innovation, and lean systems engineering and integration approaches, as well as determinations about how prior investments can be leveraged. It also will employ modern manufacturing and processing techniques, improved insight and oversight practices, and streamlined infrastructure requirements, while also reducing other fixed costs to help drive down development and operational costs, as required by the Congress.

For the SLS, the Agency has decided to use a Reference Vehicle Design that is derived from Ares and Shuttle hardware, given the Congressional direction. This vehicle concept incorporates a liquid oxygen/liquid hydrogen (LOX/LH2) core with five RS-25 Space Shuttle Main Engine (SSME)-derived engines, five-segment solid rocket boosters, and a J-2X based Upper Stage for the SLS. This approach would allow for use of existing Shuttle and Ares hardware assets in the near term, with the opportunity for upgrades and/or competition downstream for eventual upgrades in designs needed for affordable production.

This spring, NASA is reviewing industry input and alternative vehicle designs to evaluate the affordability, sustainability, and realism of all options for the SLS, including the Reference Vehicle Design. In addition, NASA is assessing whether current contracts can be legally transitioned to support SLS development efforts. NASA will make a determination on the SLS Vehicle Design in summer 2011.

The transition to the new SLS may result in impacts to the various suppliers of the Space Shuttle, ISS and Constellation Programs. The Space Shuttle uses liquid engines for its Space Shuttle Main Engines (SSME). It also uses two reusable solid rocket motor boosters. NASA solicited input from its primary suppliers to these programs in order to understand the effects of the Space Shuttle retirement and the capability of the industrial base to provide a replacement SLS. NASA is sponsoring a survey that is being conducted by the DoC Bureau of Industry and Security that includes transition and retirement as a primary focus area. Currently, we anticipate that the report of the survey will be completed in the summer timeframe.

2.0 SOLID ROCKET MOTOR INDUSTRY EFFECTS

Solid rocket motors (SRM) are used for space launch, missile defense, and strategic and tactical missile systems. Over the past 20 years, NASA was the single largest consumer of large SRM propellant, particularly aluminum perchlorate, and drove the market demand for both propellant and constituent materials. This demand was due to the production of the Space Shuttle Reusable Solid Rocket Motor (RSRM).

However, with the transition from the Shuttle to the SLS Program, as well as reductions within DoD programs and reduced competitiveness of U.S. launch vehicles in the global marketplace, the SRM industrial base is experiencing greatly reduced demand. As an example, total propellant production had decreased from 30 million pounds per year in the 1990s to less than 4 million pounds of propellant projected for 2011. This reduced demand trend is expected to continue for the foreseeable future.

Additionally, the large-SRM (greater than 40 inches diameter) industrial base infrastructure has had significant excess capacity, even with the Shuttle operating. In order to sustain the SRM industrial base and control costs, the industry must better align its capacity with the current and future large-SRM market demand. The United States has this unique capability and is the only producer of SRMs comparable to the RSRM (138 inches). (Note that the Ariane 5 and the H-IIB each use SRM strap-ons that are 118 inches and 98 inches, respectively.)

In the worst case, the dominant customer (NASA) for large-SRM propellant could potentially be leaving the customer base. The DoD has stated that this industrial capability is mandatory for the strategic defense of the U.S. Major fluctuations in demand will have impacts on the remaining customer base, to include both strategic missile and space launch programs. The Trident II D-5 program is currently in production and the build rates from year to year will be driven by planned replacements of fielded units. In addition, SRM's are also being produced in support of the EELV program as solid strap-ons that are used to support both the Atlas V and Delta IV family of vehicles.

2.1 Solid Rocket Motor Prime Suppliers

The significant drawdown of defense budgets during the 1990s and the collapse of the demand for commercial launch capabilities during the late 1990s and early 2000s resulted in significant SRM industry consolidation and underutilized production facilities. This has left two remaining prime suppliers (Alliant Techsystems, Inc. of Utah and Aerojet of California) manufacturing SRMs in the United States that have acquired or absorbed the earlier manufacturers, thereby inheriting their facilities.

The United States' space activities are conducted in three distinct but interdependent sectors: commercial, civil and national security. Solid rocket motors and their constituent materials are used to support the needs of these three sectors. Based on currently-projected civilian and defense production needs, the SRM industrial base has more capacity than will likely be required in the future.

Facility closures and consolidations are being implemented with the ramping down of the Space Shuttle RSRM program. Requisite reductions in personnel have been accomplished while retaining critical skill sets needed to continue manufacturing safe and reliable SRMs. The industry sees a continued decrease in production capability in the next 10 years, and is adjusting its workforce to accommodate current and near-term (three-to-five years) production rates.

The two prime suppliers' average production area utilization is less than 30 percent. This under-utilization provides the capacity to accommodate increased throughput in response to demand, either as a surge or on a continuous basis. As a result, the capacity and skill set may be currently available to respond to market demands from the NASA SLS. However, the length of the gap between supplying the Space Shuttle and the start up of the successor SLS program could increase the difficulty and cost of restarting production capacity of these suppliers.

2.2 Solid Rocket Motor Sub-tier Suppliers

Although the two prime suppliers currently retain the capacity and skills to supply the SLS Reference Vehicle Design, they depend upon a common supply chain that has been impacted by the general downward trend of demand for SRMs. As with the prime suppliers, the lower-tier enterprises have also experienced consolidation to where there are currently about two dozen small-to-medium size suppliers in this chain. These small-to-medium size suppliers represented about 94 percent of the SRM material costs during the peak of the Space Shuttle program.

The following are examples of materials supplied to the SRM production facilities that are identified as potential issues for continued or increased production.

- **Propellant Chemicals:** Currently, there is a single domestic source of Ammonium Perchlorate (AP). AP is the primary propellant chemical constituent in many SRMs. Due to significant and continuing downturns in the total national demand, the material price has been dramatically impacted due to amortization of fixed costs. This reality represents an affordability risk to all future SRM programs. Other propellant constituents, which are variants of other commercial products, are occasionally at-risk due to low demand and percentage of total sales.

- **Carbonizable Rayon Precursor Material:** There is no domestic source of organic carbonizable rayon material, a precursor to carbon phenolic composites used in SRM ablative nozzle fabrication. The U.S. industry is currently relying on stockpiles of aerospace-grade rayon from manufacturers that are no longer in production. Projects are underway to evaluate and characterize alternative polyacrylonitrile-based fiber technologies to determine if alternatives are viable and sustainable, although these efforts have experienced performance and schedule challenges.

- **Carbon/Carbon Billets and Combustion Throats:** There is a single domestic commercial source for the carbon/carbon billets and throats used in SRM nozzle assemblies. There is another domestic producer that uses its product in-house but does not sell it commercially.

2.3 Research and Development in Solid Rocket Motors

Investments in new technologies within the solid rocket motor community have been implemented by the industry's internal investment and through research and development sponsorship from the DoD. Activities include research in pulsed motors (rocket motors with multiple segments that allow the motor to be burned in segments that burn until completion of the segment; development of variable thrust through the use of pintle mechanisms or mechanically varying throat diameter; research into the use of insensitive munitions for propellants; and research into hybrid rocket propulsion. Hybrid rockets include a combination of liquid and solid rocket technologies where the fuel and oxidizer are stored separately and in two different phases. Current research and development efforts on hybrid rockets is focused on formulating fast burning fuels, achieving propellant stability, scaling the technology to larger motors, and in developing flight weight motors. Although the solid rocket motor industrial base has considerable excess production capacity, it is using internal and government investment to maintain critical engineering skills and utilize existing facilities and equipment.

3.0 LIQUID ROCKET MOTOR INDUSTRY EFFECTS

The U.S. space launch sector is under significant stress due primarily to the low demand of launch services, hence the decrease in the need for liquid propulsion skills and manufacturing capabilities. Since the Nation has lost a significant portion of the global market, this situation has numerous serious consequences such as the atrophy of the propulsion systems supply chain and associated loss of workforce skills and sub-tier providers. To have a healthy industrial base, the liquid propulsion system sector should have work in all phases of the lifecycle – design/development and manufacturing for sustainment/operations. In addition some of the U.S. launch capability makes use of foreign-made engines. This imbalance between supply and demand could lead to the erosion of the Nation's technical leadership should this overcapacity and low demand scenario continue.

3.1 Liquid Rocket Engine Prime Suppliers

As with the SRMs described above, there has been considerable retraction and consolidation in the liquid rocket engine industrial base the United States. There are currently two prime suppliers (Pratt and Whitney Rocketdyne of California and Florida, and Aerojet of California) of liquid rocket engines that sell engines commercially, and a third (Space Exploration Technologies of California) that produces engines exclusively for its own use. Although there are three prime suppliers, they do not have equivalent production capability. Pratt and Whitney Rocketdyne is the only U.S. supplier of liquid oxygen/liquid hydrogen engines, such as the SSME (a candidate for use in the new SLS) and the RS-68 engine currently used in the Delta IV launch vehicle. Aerojet and SpaceX supply liquid oxygen/kerosene engines with lower thrust levels.

Liquid rocket engines are used for missile defense, national security, commercial, human, and robotic space exploration launch and spacecraft applications, including the Evolved Expendable Launch Vehicle (EELV) program and other commercial launch vehicles. In response to the general trend in the industry, the prime suppliers are consolidating production capacity to "right-size" their business and reduce fixed and recurring costs by reducing production floor space, consolidating facilities, and decommissioning excess facilities and upgrading manufacturing techniques. Due to market uncertainty, the industry has been reluctant to invest in new capabilities and technologies. Limited business volume makes it difficult to maintain current capabilities or hire new staff. The technical work force is aging with retirements on the horizon; this may have some significant negative impacts on knowledge transfer to the next generation of propulsion engineers.

Future demand is highly dependent upon Federal Government decisions going forward, but recent past-trends would indicate likely reduced demand in the near term, which will result in low-volume orders, inconsistent annual rates and discontinuous production and/or production gaps. These elements are further aggravated by existing EELV inventories, which are significantly large in some cases, such that projected launch rates are driving even longer gaps in production. Additionally, customers today prefer to procure existing engines or modified derivatives to minimize integration, testing, and (re)certification costs and risk for new or existing launch vehicles.

3.2 Liquid Rocket Motor Sub-tier Suppliers

As with the SRM manufacturers, the two liquid engine suppliers generally depend upon a common supply chain. The following are examples of materials supplied to the liquid rocket motor production facilities that are identified as potential issues for continued or increased production.

- **Specialty Metal, Castings, and Forgings:** Cost and lead times have been steadily increasing over the past 24 months and the projection is for this trend to continue. Limited or low quantities required by the aerospace market often limit or dictate the supply base.

- **Engine/Propulsion Controllers:** This product area has a limited industrial base, due to vertical integration at the prime contractor level.

- **Valves and Regulators:** This critical product area has a very limited supply base of qualified technologies, with long lead-times and escalating costs. The development of alternative suppliers, although attractive, is unrealistic, due to overall schedule and funding constraints. Limited market opportunities have also thwarted industry investment and product development.

- **Electromechanical or Hydraulic Aerospace Actuators:** This critical product area also has a very limited supply base of qualified technologies, with long lead-times and escalating costs. The development of alternative suppliers is typically constrained by overall schedule and funding. The limited opportunities have also negatively impacted industry investment and product development.

- **Turbopump and Rotating Hardware Supply Base:** The turbopump and sub-tier rotating hardware supply base is limited and shared with aircraft turbine engine manufacturers. The relatively small demand quantities for space applications often limit or dictate supplier choices.

- **Liquid Oxygen (LOX), Liquid Hydrogen (LH2), Liquid Nitrogen (LN2), and Helium:** Continued production of these critical materials should be relatively stable as there are many uses for these products beyond rocket propulsion. Helium supply, however, may not be as stable. According to the National Research Council, 10 – 15 years after the completion of the Bureau of Land Management helium reserve sell off (as mandated by the Helium Privatization Act of 1996 and scheduled for implementation in 2015), the U.S. Helium supply may be inadequate for projected consumption and may lead to importation of Helium from other countries (most likely Algeria, Russia, and/or other petroleum producing countries in the Middle East).

- **Hydrogen Peroxide:** Uses for high purity (greater than 90 percent) hydrogen peroxide are limited. An industrial base could be established if the demand arises.

- **Monomethyl Hydrazine (MMH) and other hydrazines:** Only one manufacturer of these commodities exists in the United States. The vast majority (greater than 99 percent) of the production supports commercial and civil space programs. The U.S. maintains an inventory of MMH to support its space programs for the next seven to 10 years, at current consumption rates. If the domestic facility shuts-down, and demand for these products re-materialize in the future, building a new production facility will take approximately three to five years.

- **Nozzle Assembly production capability: Production of these items** terminated in mid-FY 2009. Typical new Nozzle production requires a five-year lead time. Historically, 53 suppliers in eight states have supported this capability with one critical supplier providing a large vertical braze capability unique only to the United States. Most skills have been transitioned as of June 2009.

3.3 Research and Development in Liquid Rocket Engines

Investment in liquid rocket engine development for boost engines is focused on enhancements to existing engines. For example, research on the RS-68 liquid oxygen/liquid hydrogen engine is directed at creating a more efficient and higher powered RS-68A variant for the Delta IV family of launch vehicles and on the Air Force's hydrocarbon boost 250K technology demonstrator liquid oxygen/kerosene motor. And, minor modifications and upgrades are being made to the Merlin engine, which has been flown on Falcon 9, while focusing on increasing production capacity. NASA has invested in the development of the J-2X liquid oxygen/liquid hydrogen upper stage engine as part of the Constellation program and the SLS Reference Design Vehicle assumes the use of the J-2X. As with the solid rocket motor community, internal investments in enhancing existing designs or in leveraging developments for ongoing government research are a means of maintaining critical expertise and utilizing existing facilities and equipment. There is currently little research and development activity regarding wholly new U.S. liquid rocket engines intended for use in launch vehicles. Several companies outside of the traditional aerospace prime contractors, however, are current working on new small U.S. liquid rocket engines, primarily for use in upper stages.

4.0 RELIANCE ON NON-U.S. SYSTEMS

4.1. Foreign Launch Vehicles

In addition to NASA, the Russian, European, and Japanese partners in the ISS program provide logistical support to the ISS. The Russian Soyuz spacecraft is currently used for crew transportation to and from the ISS. Cargo is delivered by a combination of the Russian Progress spacecraft launched on the Russian Soyuz launch vehicle, the European Space Agency (ESA) Automated Transfer Vehicle (ATV) launched on the European Ariane 5 launch vehicle, and the Japanese Aerospace Exploration Agency (JAXA) H-II Transfer Vehicle (HTV) launched on the JASA H-IIB launch vehicle for cargo. With the successful maiden flights of the European ATV in April 2008 and the Japanese HTV in September 2009, the availability of the Partner vehicles has been demonstrated. Manifesting and flight schedules for future ATV and HTV are actively being planned and executed. To date, the Progress vehicle has flown 33 supply missions to the ISS, the ATV has flown one mission, and the HTV has flown two missions. NASA has no plans to purchase Russian cargo services using Progress beyond 2011, but Progress will continue to be used by Russia for its supplies. The use of Russian launch services in support of the ISS is dependent on NASA's current exemption in the Iran, North Korea, and Syria Non-proliferation Act (INKSNA). This exemption will expire in July 2016.

NASA uses the Space Shuttle for both crew and cargo, but will retire the vehicle by the end of FY 2011. After this retirement, U.S. obligations for logistical support to the ISS will be transitioned to U.S. commercial and international partner cargo vehicles (the latter based on existing agreements as part of the International Partners' commitments to the ISS partnership).

Although the Progress, ATV, and HTV vehicles will continue to resupply the ISS, NASA is pursuing a U.S. commercial cargo resupply capability. As part of NASA's Commercial Orbital Transportation Services projects, NASA is providing financial assistance to help two U.S. firms (Space Exploration Technologies, known as SpaceX, and Orbital Sciences Corporation, known as Orbital) develop reliable, cost-effective access to low-Earth orbit. [1]Additionally, NASA has awarded two contracts, one each to SpaceX and Orbital for cargo resupply to the ISS under the auspices of the Commercial Resupply Services (CRS) contract.

After the Space Shuttle is retired in 2011, NASA will rely upon the Soyuz for crew transportation until a commercial capability is available. The Agency will continue to use ATV and HTV for cargo resupply, as well as domestic commercial vehicles, once they are operational. As directed in the Act, the NASA SLS also will be capable of providing a back-up capability for crew and cargo resupply to the ISS.

4. 2 Foreign Rocket Motors

Orbital's Taurus II rocket, planned for use under the company's CRS contract, will utilize a U.S.-modified, Russian-built, first-stage engine known as AJ-26. Orbital's U.S. supplier, Aerojet, has a sufficient number of the engines already in stock to meet NASA's CRS contractual needs. As part of the Air Force's EELV program, the Atlas V rocket uses a Russian-built, first-stage engine known as the RD-180. The Atlas V rocket is not currently planned for use in the COTS cargo project. However, several companies have expressed interested in using a human-rated version of this launch vehicle for eventual commercial crew transportation systems.

As mentioned earlier in this report, NASA continues to perform technical and programmatic assessments to determine the best path forward for the SLS. Assuming that current trade and analysis activities go as planned, and FY 2011 appropriations are in place, NASA will make a determination on the SLS Vehicle Design in Summer 2011. Therefore, it is too early to say what hardware elements will or will not be needed for the SLS.

5.0 CONCLUSION

The U.S. space launch industrial base is underutilized due both to lower launch rates over the last 10 years, the noncompetitiveness of many U.S. launch vehicles in the global commercial market,

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[1] The Space Act Agreements negotiated between NASA and the two COTS partners (SpaceX and Orbital Sciences) spell out in detail a schedule of performance milestones that each participant is expected to achieve along with a fixed payment to be made upon the successful completion of each milestone. These milestones culminate in a flight demonstration where the participant's vehicle will launch, rendezvous and berth with the ISS, and return safely to Earth. The funded partners are paid a pre-negotiated fixed amount only if they successfully complete a milestone. If they do not complete the milestone to NASA's satisfaction, they are not paid. These milestones can be technical (for example, a successful design review or hardware test) or financial (raising a certain amount of private funding). NASA's original investment in COTS was to be a total of $500 million. However, NASA has requested and been authorized an additional $300 million to augment the original COTS and CRS investments so that additional funded milestones can be added to the agreements to help reduce risk and increase the chances of mission success for both partners. On December 8, 2010, SpaceX successfully completed its first demonstration launch, orbit, re-entry, splash-down and recovery of the Falcon 9 launch vehicle and Dragon spacecraft. Cargo demonstration flights to the ISS by both SpaceX and Orbital are expected to be completed by the end of the year.

as well as use of foreign engines in some U.S. launch systems. The propulsion industry (solids and liquid) has significant excess capacity. The retirement of the Space Shuttle has compounded a general downward trend for the historical solid and liquid rocket motor industrial bases, resulting in a tenuous, but currently sufficient capacity, infrastructure and key skill sets among the legacy prime suppliers within the industrial base to supply the SLS Reference Vehicle Design. Some new entrants into the liquid propulsion field have developed or are developing enhancements to existing liquid rocket engines. Challenges also exist within the critical sub-tier suppliers and are reflective of the relatively low demand, lack of sustained investment, fiscally-challenging times, as well as the broader consolidation of the space industry as a whole. The longer the gap between supplying the Space Shuttle and the startup of any successor program, the greater will be the difficulty and cost of restarting production capability. In general, the supply base is shrinking, which can result in escalating costs due to limited production (or availability) and increasing project risk in terms of availability and performance of critical items. Overall, active and prudent measures across the national space community are necessary to ensure the viability of the solid and liquid industrial base sectors in order to ensure the viability of all planned programs.