EXECUTIVE OFFICE OF THE PRESIDENT
OFFICE OF SCIENCE AND TECHNOLOGY POLICY
WASHINGTON, D.C. 20502

December 22, 2009

The Honorable John D. Rockefeller
Chairman
Senate Committee on Commerce, Science, and Transportation
United States Senate
508 Dirksen Senate Office Building
Washington, DC 20510

The Honorable Bart Gordon
Chairman
House Committee on Science and Technology
United States House of Representatives
2321 Rayburn House Office Building
Washington, D.C. 20515

The Honorable Kay Bailey Hutchison
Ranking Member
Senate Committee on Commerce, Science, and Transportation
United States Senate
508 Dirksen Senate Office Building
Washington, DC 20510

The Honorable Ralph M. Hall
Ranking Member
House Committee on Science and Technology
United States House of Representatives
2321 Rayburn House Office Building
Washington, D.C. 20515

Dear Chairman Rockefeller, Chairman Gordon, Senator Hutchison and Senator Hall:

Section 1119 of the National Aeronautics and Space Administration (NASA) Authorization Act of 2008 directed the Director of the Office of Science and Technology Policy (OSTP) to "submit to Congress a report setting forth the assessment of the Director as to the capacity of the United States industrial base for development and production of engines to meet United States Government and commercial requirements for space launch vehicles."

In support of this effort, the Office of Science and Technology Policy (OSTP) tasked the Science and Technology Policy Institute (STPI)—a Federally funded research and development center that is operated by the Institute for Defense Analyses and provides analytic support to OSTP—to provide an assessment of the U.S. space launch propulsion industrial base in terms of the factors identified in Section 1119 of H.R. 6063. The information and findings provided below are based upon the results of STPI's assessment, supplemented by other data and analyses available to OSTP.

Methodology

The following assessment is based on extensive interviews with both industry participants and government stakeholders. Specifically, this report incorporates information and insights provided by representatives of nine companies, including all of the domestic propulsion and launch vehicle companies cited in the report plus additional firms in the entrepreneurial sector of the space launch industry. Further input was received from government launch customers and program managers throughout the Department of Defense and National Aeronautics and Space Administration (NASA), as well as from their supporting analysis consultants, studies, and service providers. Insight also was gleaned from numerous prior assessments of the space launch vehicle and propulsion industrial base.

The space launch industry regularly evaluates new concepts and potential markets, including proposed next generation launch vehicles and systems aimed at potential use in the 2020s and beyond, as well as new markets that include space tourism. In addition to activities supported by the U.S. Government and its traditional industrial base, the U.S. space launch industry boasts an energetic entrepreneurial sector that actively experiments with new vehicle and propulsion concepts. It would be beyond the scope of this assessment to consider all such ideas and concepts. Accordingly, the current assessment focuses on:

- **Existing markets and requirements.** Evolving market sectors such as space tourism appear to offer real business possibilities for a number of players and hold the promise of dramatically changing the space launch industry over time. Nonetheless, these markets remain unproven at this point, and there are no active launch capabilities yet available to serve such segments and demonstrate their potential. As such, these potential markets (and corresponding propulsion requirements) are not addressed in this analysis, which instead focuses on more fully established areas of demand.

- **Existing propulsion capabilities and actively funded development programs with defined requirements.** A number of emerging U.S. propulsion providers are exploring new fuels and potential engine or motor designs. Although such development efforts could lead to significant new propulsion capabilities in the future, these concepts are still largely undemonstrated and the development timelines uncertain. Because these programs do not appear to represent near-term options for supporting known U.S. Government and commercial requirements for space launch vehicles, this assessment emphasizes existing capabilities and development programs that are both actively funded and expected to provide capabilities to meet identified requirements.

Situation Assessment

Over the five plus decades since the beginning of space launch activities, the U.S. and the world have become increasingly reliant on space across a broad range of government and commercial activities. Critical government space missions include defense and national security needs, science and technology, weather forecasting, and positioning, navigation and timing services. Likewise, companies make extensive use of space in support of voice and data communications, remote sensing and observation, and positioning, navigation, and timing applications. Retaining reliable access to space is crucial to enabling (and acquiring the benefit of) these space applications and activities, and space launch propulsion systems in turn are critical elements of the space launch vehicles that enable such access.

At present, the U.S. space launch propulsion industrial base provides a diverse range of technological capabilities and more than adequate production capacity to meet most currently identified U.S. Government and commercial requirements for space launch vehicles.[1] Furthermore, there are no articulated, established space launch requirements that are beyond the current development expertise of the U.S. space launch propulsion industrial base. Nonetheless, this U.S. industrial sector is under significant stress, due largely to low demand.

Despite the importance of space to government and commercial activities, the U.S. space launch industry has seen a decline in launch rates over the past decade. While this is driven in part by the exceptional reliability of satellites and the limited need for new capabilities or services, the continued rise of foreign launch service providers has also played a significant role. On the commercial side, domestic launch service providers currently carry few commercial satellites – the majority of the world's commercial launches take place on foreign systems, primarily due to lower service prices for those systems. From 2004-2008, the U.S.-manufactured vehicle share represented roughly 17% of the commercial launch market, compared with 42% for Russia, 21% for Europe, and 18% for the multinational company Sea Launch,[2] according to the *FAA 2008 Year in Review* report. This is down from a roughly 20% market share in the early 2000s. Moreover, future demand for commercial launch activity over the coming decade appears flat, indicating that U.S. launch providers will not be able to count on growth in global market demand to increase their commercial launch opportunities. Notwithstanding these competitive pressures, the Space Exploration Technologies Corporation (SpaceX), an emerging launch services provider, has begun to attract commercial and government customers for its family of vehicles, and successfully launched a Falcon 1 rocket carrying the RazakSAT Earth Observation satellite on July 13, 2009.

While U.S. Government launch rates have not fallen as far, government launch rates since 2000 are also substantially lower than during the 1990s. From 1995 through 2000, the U.S. Government averaged 22.6 launches per year (including both civil and military launches). Since 2001, however, the U.S. Government has averaged only 15 launches per year, and roughly comparable launch rates are projected to continue through the middle of the next decade.

In addition to such trends, key business and policy decisions have further reduced the demand for U.S. propulsion capabilities. Specifically, as we will discuss below, a substantial fraction of U.S. propulsion demand is currently met by foreign suppliers. So while demand for U.S. launch vehicles is low, demand for the production of U.S. propulsion systems is even more constrained. Given this situation, most U.S. propulsion providers seem to have little business incentive for investing in new capabilities and technologies. Indeed, the limited volume makes it difficult for some providers even to maintain current capabilities as component and material suppliers shut down production lines and facilities and direct their attention to more promising markets – or even shut down completely. In addition, declining volumes make it very difficult for propulsion providers to hire new staff – and the uncertainty regarding long-term job prospects likely makes

1 As discussed in more detail in later sections, the Atlas V and proposed Taurus II launch vehicles make use of Russian-developed engines that are not manufactured in the United States.

2 Sea Launch is a partnership among The Boeing Company (Boeing) and companies in Russia, Ukraine and Norway, with Boeing owning a 40% stake. Sea Launch received approval in December, 2009 to enter into Chapter 11 bankruptcy reorganization.

the industry less appealing to entry level workforce. A potential result of such factors is a declining workforce in which key staff are increasingly eligible to retire, taking their experience base with them. This situation could in turn reduce the ability of propulsion providers to create next generation propulsion systems even if there were sufficient demand.

It should be noted, however, that there are some emerging bright spots. In particular, the U.S. is seeing the rise of a few new entrepreneurial launch services providers. With business models that emphasize reliability and cost savings rather than new technology, these providers generally are not targeting fundamental advancements in the state of propulsion technology. Nevertheless, these firms bring a new level of excitement and energy to the industry with the hope of new launch and associated propulsion systems at lower cost and, as a result, the potential for growing the market. This allows them to attract a new cohort of entry level scientists and engineers and provide hands-on experience with building and testing new engines and motors. But while promising, these entrepreneurial space launch and propulsion capabilities are still generally in the developmental stages or are otherwise not yet fully proven.

Propulsion Systems Demand Overview

To meet its non-crewed space launch needs, the United States currently has access to seven domestically produced orbital and sub-orbital launch vehicles, with an additional two vehicles currently in development (see Table 1). In addition, the U.S. plans to continue using the Space Shuttle until the current manifest is completed (scheduled for 2010) and currently is developing the Ares I and Ares V launch vehicles for use in the U.S. human space flight program.

Importantly, outside of U.S. Government operations in support of the human space flight program and strategic missile efforts, there are only three U.S. companies that provide launch services to meet these needs: the United Launch Alliance (ULA, a joint venture of Boeing and Lockheed-Martin);[3] the Orbital Sciences Corporation (Orbital); and SpaceX. These firms face substantial competition from an increasing number of foreign launch providers, including Arianespace (Europe), International Launch Services (ILS, owned primarily by Khrunichev State Research and Production Space Center, a Russian company), the Yuzhnoye Design Bureau of Ukraine, the Indian Space Research Organization, the Japanese Aerospace Exploration Agency, and the China Great Wall Industry Corporation.[4]

With respect to U.S. propulsion systems, the U.S. Government, ULA, Orbital, and SpaceX currently represent the entire demand for existing orbital U.S. space launch propulsion

[3] Technically, as part of the Federal Trade Commission arrangement that created ULA, Boeing Launch Services and Lockheed Martin Commercial Launch Services provide launch services in that they market and sign the contracts for commercial customers of Delta II, Delta IV and Atlas V, respectively, even though they in turn purchase their vehicles from ULA.

[4] Sea Launch, and its subsidiary Land Launch, could continue to be a source of competition for U.S. domestic launch service providers if the company is able to successfully reorganize and refinance as part of its ongoing Chapter 11 bankruptcy process.

capabilities although, as detailed below in Table 1, not all space launch propulsion systems acquired by the three U.S. launch vendors are from U.S. producers.

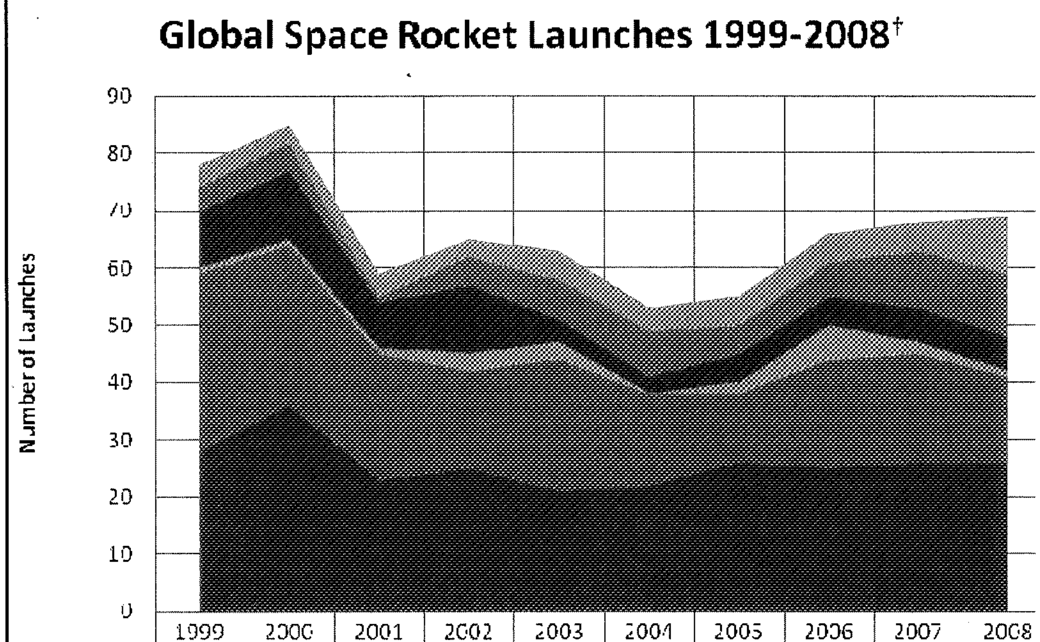
Category	Launch Vehicle	Provider	Engines/Motors	Status
Large orbital	Space Shuttle	NASA - U.S. Government	Shuttle RSRM (boosters) SSME (1st stage)	In service through 2010
	Ares I	NASA - U.S. Government	RSRM-based (1st stage) J-2X (upper stage)	In development
	Ares V	NASA - U.S. Government	RSRM-based (boosters) RS-68B (1st stage) J-2X (upper stage)	In development
	Atlas V	ULA	Atlas V SRM (boosters) RD-180 (1st stage) RL-10 (upper stage)	In production
	Delta IV	ULA	GEM-60 (boosters) RS-68 (1st stage) RL-10 (upper stage)	In production
	Falcon 9	SpaceX	Merlin (1st stage) Kestrel (upper stage)	In development
	Taurus II	Orbital Sciences Corporation	AJ26 (1st stage) Castor 30 (upper stage)	In development
Medium orbital	Delta II	ULA	RS-27 (1st stage) AJ10 (upper stage)	Out of production
	Taurus	Orbital Sciences Corporation	Castor 120 (1st stage) Orion 50/38 (upper stages)	In production
Small orbital/ suborbital	Falcon 1/1e	SpaceX	Merlin (1st stage) Kestrel (upper stage)	In production
	Pegasus	Orbital Sciences Corporation	Orion 50/38 (all stages)	In production
	Minotaur I and IV (orbital) and II and III (suborbital)	Orbital Sciences Corporation	Minuteman or Peacekeeper boosters (boost stages) Orion 50/38 (upper stages for orbital vehicles)	In production (based upon ICBM stages)

Table 1: U.S. Launch Systems

[5] NASA also conducts roughly five to twelve suborbital launches per year at various locations, using already-developed vehicle components and stages. These systems are not shown or described here. While space tourism markets and requirements are not addressed in detail in this report, it also should be noted that Virgin Galactic recently rolled out its first vehicle (known as Space Ship 2) intended for commercial suborbital human spaceflight operations. Should Virgin Galactic prove to be a successful venture, it would offer another venue for suborbital space access and research, in addition to already existing service providers.

Limited Demand – But Significant Launch Services Capacity

Over the last decade, the overall demand for the launch services provided by these three U.S. providers has reached some semblance of a steady state – although at relatively low levels and mostly for U.S. government needs (the split is roughly 80%-20% for governmental/commercial launches from 1999-2008). To put this in context, global launch rates have not exceeded 100 launches in a single year since 1990 – and have not exceeded 80 since 2000 (see Figure 1).



	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Other*	4	3	4	3	5	4	5	5	5	10
China	4	5	1	5	7	8	5	6	10	11
Europe	10	12	8	12	4	3	5	5	6	6
Japan	1	1	1	3	3	0	2	6	2	1
USA	31	28	22	17	23	16	12	19	19	15
Russia**	28	36	23	25	21	22	25	25	26	26

† Chart does not include sub-orbital launches
* Other includes Sea Launch
** Russia includes launches from Kazakstan, the major launch port for Russian launch services

Figure 1: Global rocket launches, 1999 – 2008[7]

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[6] NASA also conducts roughly five to twelve suborbital launches per year at various locations, using already-developed vehicle components and stages. These systems are not shown or described here. While space tourism markets and requirements are not addressed in detail in this report, it also should be noted that Virgin Galactic recently rolled out its first vehicle (known as Space Ship 2) intended for commercial suborbital human spaceflight operations. Should Virgin Galactic prove to be a successful venture, it would offer another venue for suborbital space access and research, in addition to already existing service providers.

[7] Sources: *2008 Space Almanac: The U.S. military space operations in facts and figures,* AIRFORCE Magazine, August 2008, pp 34-53; *2008 Commercial Space Transportation Forecasts,* Federal Aviation Administration

Within that global context, U.S. demand has also decreased substantially over the last 15 years. In 1997 the U.S. carried out 37 space launches (more launches than any other year after the 1960s) but has only averaged 19 launches per year since 2000 (see Figure 2). As Figure 2 also shows, launch rates through at least the early half of the next decade are projected to be at a similar level. (Note that, due to launch delays, projected launch rates at the beginning of any year are typically 25% to 50% higher than the number of launches that actually occur. Thus, the large apparent spike in 2009 and 2010 is expected to largely disappear as actual launches shift out in time. Consistent with this trend, the final tally for 2009 is expected to be about 20 percent less than the amount shown in Figure 2, which was based on earlier forecasts.)

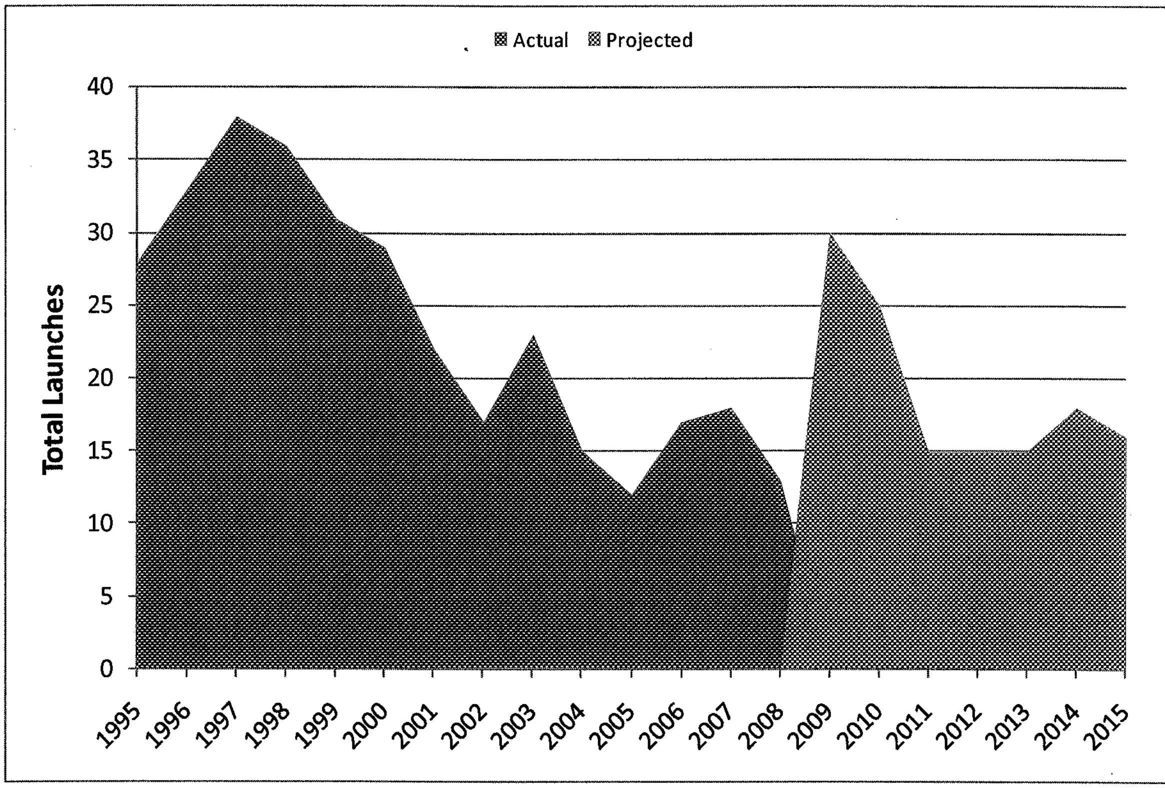

Figure 2: Actual and projected U.S. rocket launches, 1995 – 2015[8]

In addition to actual launch activity, the U.S. Government is in the final stages of the Minuteman III Propulsion Replacement Program (PRP) and plans to continue D-5 missile production through 2023.

(FAA Commercial Space Transportation (AST) and the Commercial Space Transportation Advisory Committee (COMSTAC)), May 2008; *2008 Space Competitiveness Index,* Futron; Space.com (Launch Forecast and the 1999 through 2009 Space Launch Logs); FAA *Commercial Space Transportation 1999 Year in Review,* FAA *Commercial Space Transportation 2000 Year in Review,* FAA *Commercial Space Transportation 2001 Year in Review,* FAA *Commercial Space Transportation 2002 Year in Review,* FAA *Commercial Space Transportation 2003 Year in Review,* FAA *Commercial Space Transportation 2004 Year in Review,* FAA *Commercial Space Transportation 2005 Year in Review,* FAA *Commercial Space Transportation 2006 Year in Review,* FAA *Commercial Space Transportation 2007 Year in Review, and* FAA *Commercial Space Transportation 2008 Year in Review;* input from industry experts and participants.

[8] Ibid.

During the 1990s, however, space launch providers projected significantly higher demand for launch services based primarily on expectations for aggressive expansion of satellite-based internet and telecommunication services (including low Earth orbit constellations). In anticipation of this demand, U.S. providers began development of two major new rocket systems – the Delta IV from Boeing and the Atlas V from Lockheed-Martin – with significant production capacity. However, this demand failed to emerge in a sustained manner, leaving the U.S. with a surplus of launch capacity. Indeed, at the current time, the U.S. launch industry provides a broad set of capabilities across the full range of lift requirements for meeting current and projected needs through at least 2020.

But, as discussed below, despite having a full range of launch capabilities, the U.S. launch industry – and, in particular, the propulsion sector – faces significant challenges to sustaining that capability or developing future capabilities.

Rocket Propulsion Production Review

To support domestic space launch capabilities, the United States currently relies on four boost phase liquid engines (with one more under development), three upper stage liquid engines (with one more under development), and five solid rocket motors (two of which – the Castor and the Orion – come in multiple variants) which are used as standalone boost and upper stage motors as well as strap-on boost phase motors (see Table 2).

Category	Engine/Motor	Manufacturer	Thrust (lbf)	Status
Boost phase liquid engines	RD-180	NPO Energomash (Russian)[9]	860,000	In production
	RS-68	PWR	663,000	In production
	SSME	PWR	409,000	Out of service in 2010
	RS-27	PWR	200,000	Out of production since 2006
	Merlin	SpaceX	125,000	In production
Upper stage liquid engines	RL10	PWR	22,000	In production
	AJ10	Aerojet	9,800	Out of production
	Kestrel	SpaceX	6,900	In production
Solid rocket motors	RSRM	ATK	3,300,000	Shuttle version to be phased out; currently being redesigned as the first stage for the proposed Ares I Launch Vehicle and as boosters for the proposed Ares V
	Castor	ATK	Varies (Castor 120 (Taurus) = 295,000)	In production
	Orion	ATK	Varies (Orion 50S (Pegasus) = 109,000)	In production
	GEM-60	ATK	185,000	In production
	Atlas V SRMs	Aerojet	285,000	In production
	Minuteman[10]	ATK	210,000	In production
	D-5[10]	ATK	202,000	In production

Table 2: Rocket engines and motors used on U.S. launch vehicles

As can be seen from Table 2, U.S. propulsion production capability at present is concentrated primarily in three suppliers: Pratt & Whitney Rocketdyne (PWR) and SpaceX for liquid engines (with SpaceX rapidly ramping up its development and production capability); and ATK for solid motors. Additional capability resides in Aerojet, which currently manufactures the Atlas V solid rocket motors and previously manufactured a number of liquid engines and solid motors, including the AJ10 upper stage engine used on the Delta II and the LR87 first stage engine that was used on the Titan IV (which was retired in 2005).

[9] The RD-180 is currently sold by RD AMROSS, a joint venture between Pratt & Whitney and NPO Energomash.

[10] While the Minuteman and D-5 programs are not space launch programs, both contribute substantially to the launch propulsion industrial base and, as such, are included in the propulsion overview.

The overcapacity in launch services carries over directly into the propulsion sector, but key business and policy decisions have further reduced the demand for U.S. propulsion capabilities. Specifically, while Boeing chose to work with Rocketdyne (now owned by PWR) to develop a new rocket engine when developing the Delta IV (the RS-68), Lockheed-Martin opted to use an engine manufactured by the Russian firm NPO Energomash and based on the proven RD-170 engine used in the Zenit rocket. This decision avoided the significant cost associated with developing a new rocket engine. But, as an outcome of the decision, a substantial fraction of U.S. propulsion demand is now – and will continue to be for some time – filled by foreign suppliers.

This dependence on foreign suppliers contributes to substantial overcapacity for U.S. space launch propulsion production, making it even more difficult for U.S. propulsion providers to sustain the industrial base in this area. Excess capacity for U.S. propulsion firms has already led to significant industry consolidation which, as pointed out above, has left the U.S. with one major current supplier for high thrust/high performance liquid rocket engines (PWR) and solid rocket motors (ATK), coupled with the capabilities of SpaceX in terms of lower-thrust hydrocarbon liquid rocket engines as well as Aerojet (which has significant capabilities in both the liquid and solid propulsion categories but presently has less business than these other firms). But even with this consolidation, the industry has significantly more production capacity than is strictly needed to meet current demand. While propulsion manufacturing companies report varying levels of capacity utilization, industry-wide capacity utilization appears to be roughly 50% or less.

This overcapacity has the benefit of ensuring that the U.S. industrial base has the production capacity to meet existing U.S. Government and commercial requirements for space launch vehicles, while also providing the margin to address potential surges in demand if such prove necessary. However, it also creates a number of challenges for ensuring the long-term health of that capacity. Specifically, it makes it difficult to:

- Attract qualified suppliers. Low production volumes and highly specialized requirements create significant supplier burdens, while providing only limited profit potential. As a result, major propulsion providers find it increasingly difficult to solicit bids from suppliers. Furthermore, small lots and long gaps between purchases means suppliers must often re-learn how to produce specialized components and materials for each new purchase, raising potential reliability and quality control concerns.

- Retain a qualified workforce. Diminishing industry prospects and the apparent overall scarcity of jobs provide limited appeal to potential entry-level workers. As a result, the average age of U.S. production personnel is steadily rising and critical employees are increasingly eligible to retire. Among traditional propulsion providers, for example, the average age of employees is close to 50. Thus, U.S. companies have expressed concern that it will be increasingly difficult to sustain production and troubleshoot problems as they arise.

Rocket Propulsion Development Review

The U.S. Government and private sector are currently pursuing only limited propulsion development activity in the form of R&D and in support of a small number of launch vehicle programs. The launch vehicles currently under development include the Ares I and Ares 5 (under NASA's Constellation program), the Falcon 1/1e and 9 (by SpaceX), and the Taurus II (by Orbital), with the Falcon 9 and Taurus II development efforts being pursued through co-funding arrangements between industry and NASA. Significantly, all three programs make use of existing and generally well-understood technology and are focusing primarily on reliability, streamlining production, and on reducing overall cost. As such, none of these programs are expected to develop fundamentally new propulsion concepts or technologies. The programs are, however, pursuing different approaches and are expected to have differing effects on the propulsion industrial base (see Table 3).

Launch Vehicle	Development Approach	Propulsion Industrial Base Implications
Ares I and V	• Use existing technology • Where possible, use existing, U.S. produced capabilities, modifying as needed to meet mission requirements	• Limits development of new technology • Maximizes use and preservation of existing U.S. production base • Preserves development capability but perhaps does less to attract new talent
Falcon 1/1e and Falcon 9	• Use existing, minimal-risk technology • Develop new capabilities using a rapid-prototype-iteration approach	• Limits development of new technology • Creates new production and development capability, including attracting new, entry-level talent to the industry
Taurus II	• Use existing technology • Where possible, use existing capabilities (wherever it can be acquired), modifying as needed to meet mission requirements	• Limits development of new technology • Provides low level of support to the existing propulsion industrial base on the development side but, depending on flight rate, will provide some support on the production side due to the use of the Castor-30 rocket motor from ATK for the upper stage

Table 3: Current Launch Vehicle Development Activities

To support the above launch vehicle programs, the U.S. industrial base has four engine development or modification programs underway (the AJ26 for the Taurus II launch vehicle, the J-2X for the proposed Ares I and V launch vehicles, and the Merlin and Kestrel engines for the SpaceX Falcon family of launch vehicles) and is planning an additional engine modification program (the RS-68B for the proposed Ares V launch vehicle). In addition, the U.S. Government is funding an R&D program (the Integrated High Payoff Rocket Propulsion Technology (IHPRPT) program), aimed at developing both liquid and solid propulsion capabilities, and ULA is working to upgrade the RS-68 (the new engine will be called the RS-68A) in order to increase Delta IV performance. These propulsion development activities are captured in Table 4.

Category	Engine/ Project	Program/ Launch Vehicle	Description
Existing Development	AJ26[11]	Taurus II	• Utilizes unused NK-33 engines built by the Kuznetsov Design Bureau in Russia • Not a full development or manufacturing program, the AJ26 program will replace the electronics and valves but will otherwise use the existing engines
	J-2X	Ares I/V	• Based on the J-2 engine designed and built in the 1960s and used on the Saturn I and V • Rather than designing a new engine, the J-2X program is intended to upgrade the original J-2 engine to increase efficiency and power
	Kestrel	Falcon 1	• First all-new U.S. upper stage engine since the 1970s • Rather than attempting to develop new technology, the Kestrel uses the pintle architecture[12] first used in Apollo program
	Merlin	Falcon 1/1e/9	• All-new booster engine – one of only two new U.S. booster engines developed in the past 2 decades • Like the Kestrel, the Merlin takes a low-risk technology approach using the pintle architecture first used in Apollo program
	RS-68A	Delta IV	• Intended to increase the thrust of the RS-68 engine from 660,000 lbf to 700,000 lbf
	Ares I Booster	Ares I	• Re-design of the shuttle RSRM for use as the Ares I 1st stage
Existing R&D	Hydrocarbon Boost	IHPRPT	• A technology demonstrator program intended to develop technologies for a potential new oxygen-rich, staged-combustion kerosene engine
Pending / Planned Development	RS-68B	Ares V	• Anticipated program to upgrade the RS-68 for use on the Ares V launch vehicle
	Ares V Booster	Ares V	• Redesign of the shuttle RSRM for use with the Ares V launch vehicle
	Common Extensible Cryo engine	Constellation	• Demonstrator project to test technologies and capabilities to allow RL-10 to be modified as main engine on lunar module

Table 4: Current Propulsion Development Activities[13]

The approaches being pursued in current propulsion development activities illustrate a fundamental reality of the current space launch industry: cost constraints and low volumes have led to a focus on using existing and well-understood approaches wherever possible and have

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11 The AJ26 was designed and built in the 1960s and 1970s by the Kuznetsov Design Bureau as the NK-33 and is currently out of production. Aerojet currently plans to refurbish the engines with new electronics and valves and use them on the Taurus II launch vehicle being developed by Orbital Sciences Corporation.

12 The Pintle architecture is a relatively simple architecture developed during the Apollo program and used on the lunar module landing engine.

13 Several other firms, such as XCOR and SpaceDev, among others, are supporting propulsion efforts that currently are at earlier stages of development or are intended to support other still-evolving markets such as space tourism. Consistent with the methodology described earlier, these early-stage efforts have not been described here.

eliminated many of the incentives for creating new technology. While this pragmatic approach will keep near-term launch vehicle development costs as low as possible, it also reduces (potentially to the point of eliminating) the ability of the U.S. industrial base to identify new, potentially game-changing propulsion technologies without significant government investments. The only new technology development program currently underway in the U.S. is the Hydrocarbon Boost Technology Demonstrator (HBTD) program (as part of the IHPRPT effort shown in Table 4). The HBTD program is currently in the second year of a nine-year effort and is funded through a $110 million development contract with Aerojet.

Summary Assessment of Production and Development Capabilities and Outlook

At present, the U.S. space launch propulsion industrial base provides a diverse range of capabilities and more than adequate production capacity to meet most currently identified U.S. Government and commercial requirements for space launch vehicles. Furthermore, there are no articulated, established space launch requirements that are beyond the current development capabilities of the U.S. space launch propulsion industrial base. At the same time, the selection of foreign engines for the Atlas V and Taurus II vehicles indicates that development cost and overall performance can be key factors driving design choices, perhaps especially when industry has a significant investment role in the vehicle development program and thus is seeking to optimize the business rationale for the effort.

In addition to current capabilities, emerging entrepreneurial launch service providers (such as SpaceX) represent new players that have the potential to both increase current production capability and help rejuvenate U.S. space launch propulsion development capabilities. While this certainly is a promising trend, many of these capabilities are still in the developmental stages or are otherwise not yet fully proven. Thus it is not yet clear what the full ramifications of these new launch services may be for the U.S. space launch propulsion sector.

Despite the current adequacy of the space launch propulsion industrial base to meet identified space launch needs in the near and medium term, there are a number of significant challenges that pose concerns for the long-term health of this industrial base. Specifically, the current low-level of demand for launch services combined with significant production overcapacity (and the fact that reliance on foreign suppliers has further limited dependence on the U.S. industrial base) creates challenges regarding:

- Supplier retention and quality levels.
- Workforce retention, as well as insufficient practice and learning opportunities necessary to sustain workforce skills.

Significant challenges also exist on the development side. In particular, known long-term U.S. space launch requirements likely are not sufficient to justify significant U.S. private sector investment in developing new propulsion capabilities and technologies. At the same time, only limited funds are currently being invested by the U.S. Government for U.S. space launch propulsion-related R&D activities.

Taken together, these factors raise important issues regarding:

- The nation's ability to identify potential breakthrough cost-savings or performance opportunities in launch vehicle propulsion.

- The industry's ability to attract the new talent required to create capabilities for future generations of U.S. space launch vehicles.

Both sets of challenges are potentially significant and appear to warrant further analysis and review on the part of involved U.S. Government agencies and the U.S. private sector as the nation considers how best to sustain and ultimately advance this important technology area that is vital for maintaining access to space.

The industrial base that supports space launch and space access is critical to our Nation's technological leadership, and I look forward to any further dialogue my office may have with you or other member of the Committee.

Sincerely,

John P. Holdren
Director

cc: Senator Jon Kyl, Arizona