STATEMENT OF
JEFFERY THORNBURG
SENIOR DIRECTOR, PROPULSION ENGINEERING
SPACE EXPLORATION TECHNOLOGIES CORP. (SPACEX)

BEFORE THE
COMMITTEE ON ARMED SERVICES
SUBCOMMITTEE ON STRATEGIC FORCES
U.S. HOUSE OF REPRESENTATIVES

JUNE 26, 2015

Mr. Chairman, Ranking Member Cooper, and Members of the Committee,

I appreciate the opportunity to participate in this important hearing. As this Committee reviews a path forward for ending America's dependence on Russian rocket engines, you have asked how we can achieve a competitive, domestic program that assures our Nation's access to space. This goal is achievable today, without billions in taxpayer spending and without any genuine threat of a "gap" in capability or competition.

From day one, SpaceX has leveraged American innovation and technical know-how to provide the most reliable space launch systems in history. We are proud to have contributed to providing a dependable and affordable ride to space for NASA and the world's most sophisticated commercial satellite manufacturers and operators. Today, we are regularly conducting cargo resupply missions to the International Space Station, and soon we will be flying American astronauts. We have successfully launched the Falcon 9 launch vehicle eighteen consecutive times for a mix of government and commercial customers. And, the Falcon launch system has been certified to launch the highest-value national security payloads under the Evolved Expendable Launch Vehicle (EELV) program.

SpaceX has emerged as the launch services provider of choice for customers worldwide. We have captured a large portion of the commercial launch market—previously dominated by the French and the Russians—and returned it to the United States. As the Air Force looks to ensure that it leverages a commercially viable enterprise to support national security space launch requirements (a key and repeatedly stated Air Force goal), it need not look far.

With the formal EELV certification of the Falcon 9 launch system after a comprehensive multi-year review, SpaceX is now positioned to support national security space launch in a competitive procurement environment. This summer, for the first time in a decade, the Air Force will hold a competition for EELV missions. SpaceX looks forward to competing in a fair head-to-head bid process, and appreciates the Air Force's confidence in the Falcon 9. This launch vehicle system can deliver 60 percent of DOD's manifest today. With the Falcon Heavy, which we plan to launch later this year, fly three times next year and certify soon thereafter, SpaceX will be able to launch 100 percent of the DOD's manifest.

Most relevant to today's hearing, SpaceX manufactures our launch vehicles and spacecraft—including propulsion systems—entirely in the United States. Our Merlin 1D engine, manufactured at our Hawthorne, CA headquarters, has flown to space more than any other boost-phase rocket engine involved in the EELV Program today, including the Russian RD-180 used on the Atlas V and the RS-68 and RS-68A used on the Delta IV. This is a little appreciated fact borne of the reality that each Falcon 9 flies 10 engines per flight. So, each launch of the Falcon 9 provides rapid and discernible heritage for the Merlin 1D engine, which has now surpassed the RD-180. It also bears noting that SpaceX currently produces more liquid rocket engines than any other private company in the world.

This Committee is seeking comment on a national rocket engine development program. My testimony will focus on the following key points:

1) SpaceX is contributing significantly to the U.S. launch and rocket engine industrial base in terms of launch vehicle and propulsion production output, launch infrastructure, marketshare, and research and development. More so than at any other time in the past few decades, the American rocket industrial base is innovating and manufacturing large amounts of rocket engines to meet consistent commercial and government demand. Those who decry the deterioration of the American rocket engine industrial base conveniently seem to overlook or discount SpaceX in their assessments.

2) Continued reliance by U.S. launch providers on risky foreign supply chains for major subsystems—including propulsion—has materially weakened the U.S. industrial base. Now, however, private industry is investing internal funds to restore America's leading edge in rocket technology. As a matter of industrial policy, it makes little sense to extend reliance on foreign sources of key subsystems when American technology can step in today. Multiple U.S. launch families – the Falcon 9 and Delta IV—today can together fulfill 100 percent of DOD launch requirements, independent of the Atlas V or any new rocket engine program. Others have stepped up to offer new boost-phase engine solutions, which we believe is the direct result of the first elements of competition in the EELV market in more than a decade.

3) There is no credible risk of any "capability gap" for national security launch now or in the future. Existing vehicles, including the Falcon 9 and the Delta IV, are both made in America and are certified for DOD launch. *Even if no new engine or launch vehicle is flying by the Congressionally-mandated deadline of 2019, there will be no gap.*

4) The threat of any potential gap in competition is a false premise. SpaceX's Falcon 9, ULA's American-powered Delta IV, and ULA's Atlas V can compete today in the EELV Program. By current law, ULA can purchase Russian engines for its existing $11 billion sole-source contract for 28 missions through 2019 or beyond. Following the Congressionally-mandated phase-out of the Russian-powered Atlas V in 2019, the Falcon 9, Falcon Heavy, Delta IV, and Delta IV Heavy will be able to compete, providing total redundancy for all types of launch. As the Senate Armed Services Committee states in its FY2016 National Defense Authorization Act report: "The committee is troubled by the incumbent launch provider's decision [to stop selling the Delta IV Medium to the Air Force], given the billions of dollars the taxpayer has provided to the incumbent provider to maintain the capability. The committee also believes that this decision, which may be a result of the prospect of increasing space launch competition, should not create an impression of a lack of competition." ULA's statement that it will not sell the Medium configuration of the Delta IV to the Air Force should not be construed as a lack of competition.

5) Government investment in engine industrial capability is prudent. However, any propulsion development effort should be structured to optimize public investment with a focus on propulsion technology development than can be used broadly, rather than creating an engine that is relevant only to the incumbent, already-subsidized provider and that would, in essence, fit only one vehicle. Any Government funds should be expended in ways that improve and advance our propulsion industrial base and its ability to drive innovation, including technology demonstrations and upgrades to propulsion testing infrastructure. Moreover, at minimum, there should be shared developed costs (of at least 50/50) between the Government and the contractors.

I. SpaceX Today

SpaceX is the world's largest launch services provider, measured by missions under contract. We are an American firm that designs, manufactures, and launches rockets within the United States, with minimal reliance on foreign vendors or suppliers and zero foreign reliance for any major subsystem or component. SpaceX was founded in 2002 with the goal of dramatically improving the reliability, safety, and affordability of space transportation. We have made that goal a reality. Our Falcon 9 launch vehicle, which provides medium- to intermediate-lift capability, has a primary mission success record of 18 consecutive flights. The Falcon Heavy, an intermediate- to heavy-lift launch vehicle, will debut this year, with already contracted Air Force and numerous commercial flights soon to follow.[1] Both launch vehicles are powered by our American-made Merlin engines.

For more than a decade, SpaceX has developed reliable and affordable launch vehicle systems designed from inception to meet national security space (NSS) launch requirements as defined within the EELV Program. We have concluded formal New Entrant Certification for EELV Program missions, with the Air Force certifying SpaceX's Falcon 9 launch system on May 27, 2015.

SpaceX has nearly 50 missions on manifest, representing more than $7 billion in contracts on the Falcon 9 and Falcon Heavy for a diverse and growing set of customers, including NASA, the Air Force, commercial satellite operators, and allied international governments. Most of these launches are set to be conducted before even the first competitive EELV mission will launch, further establishing our robust flight heritage. In fact, Falcon 9 will exceed the Delta IV family in flights to orbit by the end of next year. And, the Merlin 1D engine has already surpassed the Russian RD-180 in terms of flight heritage. SpaceX is a profitable, robust business; as technology companies should, we invest much of these profits back into the company's manufacturing and launch infrastructure and into advanced research and development, including current and next-generation booster propulsion.

To date, SpaceX has achieved unprecedented reductions in the cost of launch and spacecraft development, all while achieving 100 percent primary mission success, scaling our production operations to be capable of producing 40 rocket cores and 400 rocket engines annually starting in 2016. The Merlin rocket engine powering the Falcon family of launch vehicles is the only new American hydrocarbon rocket engine to be successfully developed and flown in the past 40 years. To date, SpaceX has flown more than 180 Merlin engines on its missions, representing significantly greater flight heritage than any other rocket engine flying on U.S. launch vehicles today, including more than the engines on Atlas and Delta combined.

Meanwhile, we continue to push ahead on rocket technology developments and innovations as we advance toward fully reusable launch vehicles, design the safest crew transportation system ever produced for American astronauts for our NASA customer, and test next-generation rocket engines. Critically, all of this innovation is occurring in the United States. Our launch vehicles (including engines and fairings) and spacecraft are made in America. We will never rely upon Russia for any element of the launch vehicle.

SpaceX maintains its manufacturing and engineering headquarters in Hawthorne, CA; a Rocket Development and Test Facility in McGregor, TX; and launch pads at Cape Canaveral Air Force Station (CCAFS), NASA Kennedy Space Center (KSC), Vandenberg Air Force Base (VAFB), and, soon, a commercial launch site at Brownsville, TX. We recently opened a satellite engineering and manufacturing facility in Seattle, WA. SpaceX maintains a network of more than 3,000 American quality suppliers and partners—an investment in U.S. American industrial base when others are spending abroad.

[1] SpaceX currently has Falcon Heavy launch contracts executed with the U.S. Air Force, Intelsat, Inmarsat, and ViaSat for operational missions.

II. SpaceX Propulsion and Launch Vehicle Capability

SpaceX Propulsion Experience and Development Timeframes

SpaceX has aggressively developed next-generation rocket technology and is the world's most prolific private producer of liquid-fuel rocket engines. The company has a proven history of innovation and reliability in engine development, testing and production: the current iteration of its Merlin engine offers a thrust-to weight ratio greater than 150 (the highest ever achieved) and performance equal to that of the best-performing gas-generator cycle kerosene engines ever built.[2]

We develop all of our engines in-house and in the United States. The company is currently on its fourth generation of booster engines, which have included the Merlin 1A, the Merlin 1B, the Merlin 1C, and the Merlin 1D. In addition, we have developed the Kestrel vacuum engine, the Merlin 1C vacuum engine, and the Merlin 1D vacuum engine for our second stages on Falcon 1, Falcon 9 and Falcon Heavy. SpaceX has also developed and Draco and SuperDraco engines which provide in-space and abort propulsion capability for Dragon (recently, we successfully demonstrated the SuperDraco engine in a pad abort test for NASA). We are also moving forward with significant R&D on a next generation rocket engine—Raptor. As the company moves forward with the advanced Raptor rocket propulsion system, we will leverage our significant past experience with rapid development of reliable and affordable engines.

SpaceX has successfully developed the 9 rocket engines mentioned above in the past 13 years. In the case of the Merlin 1C, which powered two successful Falcon 1 missions and the first five Falcon 9 missions, the engine went from design to flight in just two years. The follow-on Merlin 1D, which currently powers the Falcon 9 and has more flight heritage than the first stage engines on the Atlas V and Delta IV combined, went from development to first flight in less than two years. These engines are not clones of past designs; the Merlin 1D is the most efficient rocket engine in history by thrust-to-weight ratio and is the only system in the world that enables a true engine-out capability for a launch vehicle system. Most importantly, SpaceX has a 100 percent primary mission success rate on its Falcon 9 launch vehicle.

Merlin

The Merlin 1D rocket engine—which powers the Falcon 9 and Falcon Heavy first and second stages—is a human-rated engine with high structural margins and a highly reliable, redundant ignition system. Rigorous qualification and acceptance testing from the component to the vehicle system level are part of SpaceX's "test what you fly" approach, and the company uses liquid-fueled engines and non-pyrotechnic, resettable separation systems that allow testing of actual flight hardware before flight.

Nine Merlin 1D engines power the first stage of every Falcon 9 vehicle, and an additional Merlin engine modified for vacuum operation propels the second stage. As noted, the Merlin engine has now successfully flown to space more than 180 times (with 130 on the Merlin 1D), reliably delivering multiple payloads for U.S, Government and commercial customers to complex orbits. Due to the engine's highly manufacturable design, SpaceX is now producing 4 Merlin 1D engines per week, with current production capacity to produce 5 engines per week—far more than any other private rocket engine producer in the world.

While Merlin 1D is not a one-to-one replacement engine for the RD-180, the nine Merlin 1D engines that collectively form the power source for the first stage of the Falcon 9 launch vehicle provide significantly more thrust at liftoff than the baseline Atlas V rocket and offer enhanced reliability features like engine-out capability. More than this, because the Merlin engine is made in America, the Air Force and other

[2] Space Launch Report. "SpaceX Falcon 9 v1.1 Data Sheet." Updated April 27, 2015. Available at: http://www.spacelaunchreport.com/falcon9v1-1.html

Government customers have insight into its reliability and production to a much greater degree than possible for the Russian RD-180.

With our existing manufacturing facility in Hawthorne, CA, SpaceX is currently capable of producing 18 cores and 200 engines per year (a core is a booster with nine engines, similar to a Falcon 9 first stage). This year, we will be at a pace of producing greater than 24 cores per year, and we are adding equipment to expand production capacity to be capable of producing 40 launch vehicle cores per year, as our manifest demands it.

For test operations, SpaceX's 4,000 acre Rocket Development Facility in Central Texas includes 12 test stands that support engine component testing; design, qualification and acceptance testing of Merlin engines; structural testing of the first and second stages; and fully integrated stage testing for full mission durations. The state-of-the-art facility has remote and/or automatic controls and high-speed data acquisition systems, and post test data are available for analysis upon test completion. To date, more than 4,000 Merlin engine tests—including nearly 50 firings of the integrated first stage—have been conducted at the site's multiple test stands. Currently, we conduct an average of two static-fire engine tests there each day.

Falcon Heavy

SpaceX is currently building and qualifying the Falcon Heavy Launch System, including launch sites to support Falcon Heavy launches. SpaceX designed Falcon 9 and the Falcon Heavy from the outset to meet EELV design specifications, including the EELV Standard Interface Specification (SIS) and System Performance Requirements Document (SPRD), at no charge to the U.S. Air Force. SpaceX is self-funding the development of the Falcon Heavy.

Between the Falcon 9 and Falcon Heavy systems, SpaceX will be in a position to support 100 percent of national security launch requirements. Coupled with the Delta family of rockets, for the first time in EELV Program history, the United States will have true assured access to space with two separate launch vehicle families, each of which can execute all mission requirements. Such an approach eliminates the risks associated with continued reliance on the RD-180 engine, and provides ample time for other providers to develop new, American launch systems, obtain EELV certification, and enter the market to compete.

On April 14, 2015, SpaceX submitted an updated Statement of Intent (SOI) to certify the Falcon Heavy launch system. The Falcon Heavy launch system offers unique reliability features through architectural design redundancy, with performance capability that greatly exceeds any current launch vehicle in the EELV fleet. Here, SpaceX proposed completing Category 3 certification through the Alternative 3 criteria, which requires three qualifying Falcon Heavy flights. SpaceX intends to leverage lessons learned during the Falcon 9 launch system certification process and the findings of the Welch Independent Review Committee (IRC) on EELV New Entrant Certification, to ensure an effective, robust, and efficient certification process for Falcon Heavy.

Falcon Heavy is under contract to launch an Air Force mission—Space Test Program-2 (STP-2)—in 2016. SpaceX also has signed contracts to launch several commercial telecommunications satellites for Inmarsat, ViaSat, and Intelsat in the next few years. We are seeing significant commercial market demand for Falcon Heavy, particularly given the recent failures of the Russian Proton launcher and the increased heavy pricing on the French Ariane 5 launch vehicle. In advance of these missions, SpaceX plans to self-fund a demonstration launch of Falcon Heavy, with the current goal of initial launch in late 2015.

Raptor

Leveraging our design, fabrication, and testing experience on the Merlin engines, SpaceX has already begun internally-funded development and testing on our next-generation Raptor engine. Raptor is a reusable LOX/methane staged-combustion engine designed for high performance, cost effectiveness, and long life in high production volume. The engine utilizes a full flow staged combustion cycle, promising the highest performance possible for a methane rocket engine, while also delivering long life through new SpaceX technologies and more benign turbine environments. SpaceX is currently testing key Raptor components at a test facility within NASA's Stennis Space Center in Mississippi and at our SpaceX McGregor, TX test facility.

Raptor represents a fundamental advancement in propulsion technology. This staged-combustion system will not only be extremely powerful, but it will also be extremely efficient and reliable. It will achieve commercial viability through notable risk- and cost-reducing improvements in metallurgy and producibility, as well as revolutionary technologies enabling long term reusability. All of these features are crucial in ensuring affordable assured access to space for the United States. Rather than turning to decades-old technology developed to support last-generation launch systems, Raptor will advance the state-of-the-art and ensure the US remains the global leader in rocket propulsion technology.

Raptor could have significant applications for national security space launch, all while significantly advancing U.S. industrial capability and technology with respect to liquid rocket engines. With a highly scalable engine cycle, Raptor's "light and tight" design is built for operational functionality, cost efficiency and long life in high production volume, which makes it ideal for NSS needs. The engine utilizes a closed cycle with the objective of achieving the highest performance possible for a methane rocket engine while also delivering extended reusability through new SpaceX technologies and more benign turbine environments. Key engine components and large structures have been additively manufactured, and Raptor will be the first large liquid engine in the world constructed largely with printed parts.

Raptor directly contributes to the rapid advancement of oxygen-rich and full-flow staged combustion and additive manufacturing technologies for the United States—enhancing U.S. industrial capability. Further, the engine enhances state-of-the-art, high-performing EELV-class propulsive capabilities for future flight engine systems to support commercial and NSS applications in accordance with Fiscal Year 2015 National Defense Authorization Act (FY15 NDAA), Section 1604. The flexibility of the Raptor design enables the technology to be applied to existing EELV-certified launch vehicles.

Importantly, SpaceX capability to support all NSS missions is *independent* of Raptor development; Falcon 9 and Falcon Heavy together exceed the DOD's requirements and will not require external development funds related to this engine. Beyond the existing and imminent Falcon family of launch vehicles, the Raptor engine provides great promise for additional capability that could be relevant to the national security space community and advance the U.S. industrial base.

III. National Rocket Engine Development Program

SpaceX understands that due to the very real concerns that have been expressed by Congress, the national security community, and the White House regarding reliance on the Russian RD-180 rocket engine, the desire to stop U.S. taxpayer outlays to Russia and its oligarchs, and the need to maintain assured access to space, the Congress has authorized and appropriated funds for new rocket engines. Meanwhile, the Air Force—which does not purchase launch hardware but rather launch services—has sought authority to co-invest with industry for new or modified vehicle launch systems, including new or modified rocket propulsion systems, in an effort to ensure the existence of at least two domestic, commercially viable launch service providers able to meet the entire spectrum of NSS launch requirements no later than the early 2020s.

As a general matter, SpaceX strongly supports sound U.S. investment in liquid propulsion technology development and test stand infrastructure that will benefit the entire U.S. industrial base. However, we remain concerned about the Congressionally-funded engine development program as currently constructed. Congressional direction in the FY2015 NDAA calls for a rocket engine that will ostensibly be "universal" and available to all prospective launch services providers. It calls only for a rocket engine, not the associated launch vehicle system for which it will be designed. The FY2016 NDAA ratifies and extends this approach, insisting that such funds be used "only for the development of such system, and the necessary interfaces to the launch vehicle."

The Air Force and the Department of Defense have rightly raised concerns with these legislative prescriptions, noting that such an approach runs the risk of continuing a long line of Government programs that have spent billions of taxpayer dollars without producing a viable flying space system. According to the White House's Statement of Administration Policy:

> Developing a rocket propulsion system independent of the rest of the space launch system risks the Government investing hundreds of millions of dollars without ensuring the availability of operational launch systems. Sound systems engineering principles and over a half-century of launch vehicle design work demonstrate that a rocket propulsion system must be developed in conjunction with the rest of the space launch vehicle. The Administration is committed to the same goals for space espoused in the bill -- assured access to space via commercially-viable, competitive, domestic launch providers using U.S.-developed launch systems for national security space. Sections 1603-1606 would impede achievement of those goals.

An undesirable outcome for the Department of Defense and the taxpayer is to spend significant sums to develop a rocket engine for which there are not multiple customers and very possibly no customer, for which there is no launch vehicle system, and which does not advance the technology in liquid propulsion.

SpaceX can confirm for the Committee that at no time will we rely on an external source, whether foreign or domestic, to provide us with a propulsion system for our rockets. SpaceX will continue to source this critical subsystem internally.

Russian Supply Chain's Questionable Reliability

As this Committee knows, the United States today is deeply reliant on Russia for national security space launch. This dependence was never intended—the original hope of partnering with Russia on rocket engines after the collapse of the Soviet Union was to contribute to non-proliferation objectives, never to become dependent on Russia for access to space. When the decision was made to partner with the Russians on the RD-180, policy-makers implemented important policy safeguards (e.g. a requirement to establish domestic co-production capability) to ensure that the U.S. would never been dependent on a foreign power for access to space. Over time, these policies and contractual requirements were ignored or waived.

At this point, there is a well-understood political risk to relying on Russia for space hardware, but there is also a technical risk. As senior Russian leaders have noted numerous times, they can cut off supply of the RD-180 engine (or the engineering services associated with the engine) to the United States at will. The thought process now would appear to be that the Russian military is so dependent on these hundreds of millions of dollars in payments that they will continue selling the engine indefinitely. These are the same funds that, as a November 2014 Reuters investigation discovered, may be going to personally enrich Mr.

Putin's inner circle and, worse yet, are used to "modernize" Russian missile technologies being exported to places like Iran and Syria.[3]

But, it is also technically risky for the United States to continue to use these engines for national security space launch. In recent years, Russian rockets and space systems hardware have experienced a significant rate of failure. Since 2013, nearly 90 percent of the world's failed launches have used Russian rocket engines, including every failure in 2014 and 2015.[4]

Despite Russian government's recent efforts to further centralize the space industry in an attempt to turn the tide of these failures, the risk to flight success continues to grow. About 80 percent of Russian production equipment exceeds designated operational limits by more than 20 years and may present significant quality issues.[5] December 2011 photographs inside NPO Energomash, the manufacturer of the RD-180, show a decrepit, nearly-deserted complex.[6] One explanation may be the rapid loss of institutional aerospace knowledge and machining skills that has occurred in Russia since the end of the Cold War. Indeed, the average age of engine construction teams now exceeds 50 years old in Russia, where the life expectancy of men is just 60 years.[7,8]

Assured Access to Space

This Committee and the Air Force have highlighted the need for assured access to space for critical national security payloads. SpaceX stands ready to support this policy. This sound requirement, established in the National Space Transportation Policy (NSTP), calls for two, independent launch systems capable of fulfilling the full spectrum of our national security launch needs. It bears noting, this goal has never been achieved in the history of the EELV program. Indeed, the absence of redundant Heavy lift capability, the increasing commonalities between the Delta and Atlas systems (especially with respect to upper stage propulsion), and the reliance on a non-secure foreign supply chain for critical propulsion systems, fail to meet policy.

Of the current ULA EELV families, only the Delta IV currently meets the full spectrum requirement. The Atlas V cannot conduct heavy lift, and thus the potential retirement of the Atlas system does not reduce EELV Program capabilities. In fact, elimination of the RD-180 after Phase 1 of the current EELV buy actually improves assured access by ending the Government's reliance on non-secure Russian rocket systems. Once Falcon Heavy launches, there will no longer be a gap, as there is today, in assured access for heavy lift launch.

The So-Called "Capability Gap:" A Fiction Created by the Delta IV Medium's Premature Retirement

It is important to note that there is no "gap" in national security launch capability, nor will there be in the future. As mentioned, SpaceX is now a certified provider of NSS launches with our Falcon 9 launch system. With Falcon 9 certification concluded, SpaceX and the Air Force are transitioning to formal certification activities for Falcon Heavy, as described above.

---

[3] Leone, Dan, "Notwithstanding Sanctions, ULA Standing By for RD-180 Deliveries through 2017," *SpaceNews*, Aug. 2014, http://spacenews.com/41507notwithstanding-sanctions-ula-standing-by-for-rd-180-deliveries-through/#sthash.doY9USx9.dpuf

[4] Nine rocket launches have failed since 2013, of which 8 have used Russian engines.

[5] *Russian Space Industry Needs Urgent Modernization,* Moscow Agenstvo Voyennykh Novostey via http://carnegie.org/fileadmin/Media/Publications/PDF/spaceFuture.pdf

[6] Hanrahan, Jake, "In pictures: Sneak inside a Russian rocket factory," *Wired*, Mar. 2012, http://www.wired.co.uk/magazine/archive/2012/05/start/sneak-inside-a-rocket-factory/viewgallery/275546

[7] Bidder, Benjamin, "Russia's Soyuz Program Crashes and Burns," *Der Spiegel,* Aug. 2011, http://www.spiegel.de/international/world/0,1518,783210,00.html

[8] Wong, Grace, "Russia's Bleak Picture of Health," *CNN,* May 2009, http://edition.cnn.com/2009/HEALTH/05/19/russia.health/index.html

With the Falcon 9 and Falcon Heavy, SpaceX joins Delta IV in meeting all of our national security launch requirements, providing the Government with two, independent launch systems capable of doing so well in advance of any competed heavy lift mission. This will close the *existing* gap in heavy lift capability.

ULA has announced in recent weeks that it plans to terminate sales of all single core configurations of the Delta IV vehicles in 2018 but to continue offering the Delta IV Heavy variant indefinitely. ULA has acknowledged that this will result in higher prices for the Delta IV Heavy. To replace the medium configuration of Delta IV, ULA has suggested it will develop the "Vulcan" launch vehicle. It purports to justify this action as a means to "lower costs."

To backfill this self-imposed reduction in its own capabilities at a time when it is suggesting there will be a "gap" in launch, ULA also seeks a change in federal law to enable it to buy more Russian engines for the medium-lift Atlas V through at least 2023. These choices will cost the U.S. taxpayer more money, and unnecessarily extend dependence on Russia and finance Russian military capabilities with U.S. taxpayer dollars. Moreover, the retirement of the Delta IV, which uses the proven American-made RS-68A engine, *weakens* the liquid propulsion industrial base here at home.

Congress should be skeptical of this approach for a number of reasons:

1) By prematurely taking all of the single core (medium-lift) configurations of the Delta IV vehicle offline by refusing to sell the vehicle to the Government—a vehicle which the Government paid for and continues to pay for its annual sustainment—an environment is created needlessly to justify additional taxpayer outlays to support ULA's business.[9] Notably, ULA opts for this course of action rather than increase production, as it has expressly stated to Congress it could do, which would result in lower unit costs for the Delta vehicles.

2) ULA's business strategy would reverse the Government's previous "contingency plan" under the assured access policy to leverage American-made Delta IV capability if there was an issue with Russian reliance. In fact, initially after the RD-180 supply was threatened by high-ranking officials in the Russian government, the plan was to increase Delta IV production immediately. In May 2014, *SpaceflightNow* reported that ULA had begun to ramp up production of the Delta vehicles in the days following Russian Deputy Prime Minister Dmitry Rogozin's threat to cut off the supply in retaliation for U.S. sanctions:

    > "[h]astening the pace of Delta 4 manufacturing could reduce its cost in the long run, perhaps bringing its price into parity with the Atlas 5, according to Gass. 'The premise right now in the price sheet is that Delta 4, by similar capability, is more [expensive] than Atlas, but those were prices based on a certain build rate,' Gass said. 'Now, we're going to accelerate the build rate, and the Delta prices will come down accordingly. How much? We've got to go negotiate how much.'"

    Notably, "Vulcan" intends to use Delta IV tanks and machining[10], which suggests that the decision to retire the medium configuration of the Delta IV is driven more by ULA's business strategy than national security.

[9] Stephen Clark. "With questions swirling, ULA hastens Delta 4 production." *SpaceflightNow*. May 19, 2014. "Gass told reporters Monday the decision to ramp up Delta 4 rocket production was part of a contingency plan adopted by ULA under the U.S. Defense Department's policy of assured access to space, which led to the development of the Atlas 5 and Delta 4 rocket families in the 1990s. . . 'The first thing we're doing is making sure we're implementing that contingency plan, which includes the acceleration of Delta 4 production, so some of that work is underway,' Gass said." Available at: http://spaceflightnow.com/news/n1405/19delta4/#.VQS5t47F_9Y
[10] Mike Gruss. "ULA's Vulcan Rocket to be Rolled Out in Stages." *Space News.* April 13, 2015. Available at: http://spacenews.com/ulas-vulcan-rocket-to-be-rolled-out-in-stages/

3) Congress and the Air Force should insist that offerors of launch services self-finance systems, in part or in whole, to meet customer requirements, to the extent an offeror wishes to be *viable competitor* in the national security launch market. SpaceX has already proven that a robust global commercial launch market exists and more than justifies contractor investment in new systems. The real benefit of competition is not only true assured access to space, but also contractor-funded innovation to improve product reliability, enhance customer service, and meet customer needs.

4) The incumbent has raised concerns as to whether the Delta IV can adequately compete with SpaceX. We question this assertion, especially since the taxpayer has spent hundreds of millions of dollars improving the first stage engine on Delta IV in an effort to improve performance and reduce costs. ULA should work to improve the efficiency and production of this vehicle. If it loses in head-to-head competitions, then this reflects a competitive landscape, plain and simple. Clearly, the most cost-effective way to achieve true assured access to space is to keep the Delta program online, eliminate the Launch Capability (ELC) subsidy, and expand competition for New Entrants. This approach requires not a single dollar of additional Government investment and will result in assured access immediately. Importantly, none of the incumbent's launch vehicle systems is "price competitive" with SpaceX launch vehicles today—including the Atlas V, which is twice as expensive as a Falcon 9 even before the ELC subsidies are accounted for.

"Commercial Viability"

In addition to having assured access to space, it is important the launch providers be commercially viable so that the Government is no longer required to pay full freight for launch services and can end the "Launch Capability" payments currently made to the sole source incumbent. The Air Force has expressly stated that its goal at the end of any engine development program is to have two commercially viable competitors in the EELV Program. Accordingly, each domestic provider of launch services must take the necessary steps to ensure it is commercially viable.

SpaceX used internal funds to develop and demonstrate our Falcon family of rockets, and we have demonstrated the commercial viability of our launch vehicle systems by unilaterally bringing U.S. market share in the global commercial, geosynchronous launch market from 0% in 2012 to more than 50% expected in 2016 (based on number of launches per year). This same level of commitment should be expected from other contractors who wish to compete in the EELV Program. At a minimum, any engine development should fall within the bounds of a public-private partnership in which corporations contribute at least 50 percent to the effort.

SpaceX discourages the Government from fully financing the development of a rocket engine unaffiliated with a launch vehicle system. The development of any such systems should be significantly funded by private industry in order to ensure commercial viability. *If such systems would not be developed absent Government funding or the promise of (not just potential for) future Government business, then they are by definition not commercially viable, and commercial viability is crucial for ensuring affordability, innovation, and reliability.* A public private partnership model, such as what the Air Force has proposed as its acquisition strategy, would contribute to its goal of the program resulting in commercially viable participants.

Neither of the incumbent EELV launch vehicles is commercially viable, including the Atlas V, which is why these vehicles have virtually no commercial marketshare. The retirement of the Atlas family will yield significant savings to the Government, as it will no longer need to sustain all contractor operations costs associated with that launch vehicle and its launch infrastructure. There should be an enormous cost reduction garnered by ending the Atlas and the currently higher-priced Delta unit costs should certainly decrease with resulting increased production. Since Delta is fully compliant with EELV requirements, it clearly can be utilized until a next-generation system is developed by the current EELV provider. At a minimum, we would recommend that the Government study the economic effects of increasing rate production of the Delta IV, while off-ramping Atlas V and associated costs, and make a determination as to what will be the lowest cost alternative to maintain assured access to space.

Since 1998, the Government has invested nearly a billion dollars in the development and enhancement of the Delta IV, not including payments for launch services, launch infrastructure, and launch capability—it should seek a return on that investment. Delta IV is an important vehicle to maintain U.S. industrial capability for liquid propulsion development and manufacturing capability, since the Delta engines are made in the United States, unlike the Atlas engines, which are made in Russia.

*****

Mr. Chairman, I appreciate your invitation to testify before the Committee today. SpaceX fully understands and supports the Government's intent to have at least two, commercially viable providers capable of performing the full spectrum of national security launch requirements. A fully Government-funded engine program under the constraints so far imposed by Congress may not result in this outcome.

An alternative approach, and consistent with the U.S. Air Force's current planning, SpaceX recommends that Congress allow for a broader set of investments into propulsion technologies, prototypes, test infrastructure, and advanced systems in order to enhance the U.S. liquid propulsion industrial base more broadly than an effort to fund a single engine (with potentially retrograde technology) would ever do. In any event, significant corporate contributions should be required.

The most rapid and cost-effective way to achieve this capability is to expand competition, create proper incentives for industry to self-invest or co-invest with the Government to meet customer requirements, eliminate American's reliance on Russian rocket engines as soon as possible, control costs, and end the practice of subsidizing launch services providers.