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ASSURING NATIONAL SECURITY SPACE: INVESTING IN AMERICAN INDUSTRY TO END RELIANCE ON RUSSIAN ROCKET ENGINES

HEARING

BEFORE THE

SUBCOMMITTEE ON STRATEGIC FORCES

OF THE

COMMITTEE ON ARMED SERVICES
HOUSE OF REPRESENTATIVES

ONE HUNDRED FOURTEENTH CONGRESS

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CONTENTS

Page

STATEMENTS PRESENTED BY MEMBERS OF CONGRESS

Cooper, Hon. Jim, a Representative from Tennessee, Ranking Member, Subcommittee on Strategic Forces 2
Rogers, Hon. Mike, a Representative from Alabama, Chairman, Subcommittee on Strategic Forces 1

WITNESSES

Bruno, Salvatore T. “Tory,” President and Chief Executive Officer, United Launch Alliance 3
Culbertson, Frank, Jr., President of Space Systems Group, Orbital ATK 6
Greaves, Lt Gen Samuel A., USAF, Commander, Air Force Space and Missile Systems Center 34
Griffin, Dr. Michael D., Deputy Chair, RD–180 Availability Risk Mitigation Study 36
Hyten, Gen John E., USAF, Commander, Air Force Space Command 33
McFarland, Hon. Katrina G., Assistant Secretary of Defense for Acquisition, Department of Defense 32
Meyerson, Robert, President, Blue Origin 4
Thornburg, Jeffery, Senior Director of Propulsion Engineering, SpaceX 8
Van Kleeck, Julie A., Vice President, Advanced Space and Launch Systems, Aerojet Rocketdyne 5

APPENDIX

Prepared Statements:
- Bruno, Salvatore T. “Tory” 63
- Culbertson, Frank, Jr. 103
- Greaves, Lt Gen Samuel A. 143
- Griffin, Dr. Michael D. 154
- Hyten, Gen John E. 135
- McFarland, Hon. Katrina G. 128
- Meyerson, Robert 79
- Rogers, Hon. Mike 61
- Thornburg, Jeffery 113
- Van Kleeck, Julie A. 86

Documents Submitted for the Record:
- Section 1604, from “Carl Levin and Howard P. “Buck” McKeon National Defense Authorization Act for Fiscal Year 2015, Legislative Text and Joint Explanatory Statement to Accompany H.R. 3979, Public Law 113–291” 163
- Liquid Rocket Engine—Multi Program Applicability 164

Witness Responses to Questions Asked During the Hearing:
- Mr. Coffman 168
- Mr. Lamborn 167
- Mr. Rogers 167

Questions Submitted by Members Post Hearing:
- Mr. Bridenstine 177
- Mr. Brooks 178
- Mr. Coffman 176
- Mr. Cooper 172

Page

QUESTIONS SUBMITTED BY MEMBERS POST HEARING—Continued
Mr. Rogers 171
Mr. Turner 180

ASSURING NATIONAL SECURITY SPACE: INVESTING IN AMERICAN INDUSTRY TO END RELIANCE ON RUSSIAN ROCKET ENGINES

HOUSE OF REPRESENTATIVES,
COMMITTEE ON ARMED SERVICES,
SUBCOMMITTEE ON STRATEGIC FORCES,
Washington, DC, Friday, June 26, 2015.

The subcommittee met, pursuant to call, at 9:03 a.m., in room 2118, Rayburn House Office Building, Hon. Mike Rogers (chairman of the subcommittee) presiding.

OPENING STATEMENT OF HON. MIKE ROGERS, A REPRESENTATIVE FROM ALABAMA, CHAIRMAN, SUBCOMMITTEE ON STRATEGIC FORCES

Mr. ROGERS. Good morning. I want to welcome everybody to our Strategic Forces Subcommittee hearing on "Assuring National Security Space: Investing in American Industry to End Reliance on the Russian Rocket Engines."

Before I get started, I think we all ought to take note today that this is the day of the funeral, those nine families in South Carolina. And it is a real tragedy. And I know our hearts and thoughts are with them and our condolences to their family and friends. As for today's business, we will be conducting two panels. In this first panel, we have five expert witnesses from the industry who represent current and potential providers of the space launch and rocket propulsion for the Evolved Expendable Launch Vehicle [EELV] program.

In our second panel, we have three senior government officials who have responsibilities in managing and overseeing the EELV program. And we also have an expert adviser to the government on recent launch study.

On panel one, we have Tory Bruno, president and CEO [chief executive officer] of United Launch Alliance [ULA]; Mr. Rob Meyerson, president of Blue Origin; Ms. Julie Van Kleeck, vice president, advanced space and launch programs at Aerojet Rocketdyne; Mr. Frank Culbertson, president of space systems, Orbital ATK; and Mr. Jeff Thornburg, senior director of propulsion engineering at SpaceX. I thank all of you for participating in this hearing, providing your perspective on national security. I know it takes time and energy to prepare for these things. And it is really an inconvenience to come up here, but it really helps us a lot in developing public policy.

So I really appreciate your service. This is our second hearing we recently conducted on space. We are dedicating the time to this topic because of its significance to our national security. Without an effective space launch program, we lose all the advantages we gain from space capabilities. Losing space for our warfighters is not an option. There are key policy and acquisition questions regarding the future of national security space that need to be addressed. As we have said before, I am committed to ending our reliance on Russian rocket engines for national security space launch.

I believe we must end our reliance in a manner that protects our military's assured access to space and protects the taxpayers by ensuring we don't trade one monopoly for another. The House bill accomplishes this. And I look forward to perspectives of our witnesses on the current legislation under consideration for fiscal year 2016 NDAA [National Defense Authorization Act], both the Senate version and the House version.

Because we are committed to ending our reliance on Russian engines, we must invest in the United States rocket propulsion industrial base. Investment in our industry for advanced rocket engines is overdue. While we may lead in some areas of rocket propulsion, we are clearly not leading in all. This is a painfully obvious fact considering that two of the three U.S. launch providers we have here today rely on Russian engines.

And it is not just the Russians leading the way. According to online press reports, the Chinese may be flying a new launch vehicle on a maiden flight this summer with similar technologies as the Russians, using advanced kerosene engine. The time has come to resume U.S. leadership in space. And I believe the companies before us today can help us do that.

However, I am concerned with the Air Force's recent approach in what may amount to a very expensive and risky endeavor in development of new engines, new launch vehicles, and new infrastructure. Congress has only authorized funding for the development of a rocket propulsion system. Launch vehicles are not the problem. The problem is the engine.

Thank you for being with us this morning. I look forward to your testimony and discussion of these important topics. I now recognize my friend and colleague from Tennessee, the ranking member, Mr. Cooper, for any opening statement he may have.

[The prepared statement of Mr. Rogers can be found in the Appendix on page 61.]

STATEMENT OF HON. JIM COOPER, A REPRESENTATIVE FROM TENNESSEE, RANKING MEMBER, SUBCOMMITTEE ON STRATEGIC FORCES

Mr. COOPER. Thank you, Mr. Chairman.

I think we should approach this hearing as all others with a great deal of humility. Because I think the bottom line is if we had gotten last year's NDAA right, we wouldn't even be having this hearing. So we are correcting a self-inflicted wound here. Now, there are many self-inflicted wounds depending on how far back you want to go in history. It is a little embarrassing for America that we haven't been able to duplicate or exceed the Russian technology already, given the billions of dollars we have expended. But, actually, there are tremendous signs of hope because if we had this hearing a few years ago, that is when we really should have been worried, but we weren't smart enough to be worried back then.

Now due to the investment, sometimes of our own billionaires and their love of space, there are some amazingly exciting things happening. So we are really just managing this transition.

I am confident we can do it. I wish, and I don't know whether the Chinese with their Long March missile have, in fact, bought the RD–180 or at least copied it successfully, something we apparently have been unable to do. But we don't want to just be held to the past standard. There are new generation technologies that are even more exciting, more capable. So how do we effectively transition to that. Company competition can be contentious sometimes, but it is also exciting. And sometimes it brings out the best in us no matter how painful it is. So I am glad we are having this hearing. I hope that the net result will be superior congressional performance, as well as superior company performance so that we can have assured access to space.

Thank you, Mr. Chairman. I look forward to the testimony of the witnesses.

Mr. ROGERS. I thank the gentleman.

And the Chair would inform the other members if they have opening statements, they can submit them for the record.

Now we will move to our first panel. The witnesses are asked to summarize their opening statements. Your full opening statements will be accepted into the record.

And we will start with Mr. Bruno. You are recognized for 5 minutes to summarize your opening statement.

STATEMENT OF SALVATORE T. "TORY" BRUNO, PRESIDENT AND CHIEF EXECUTIVE OFFICER, UNITED LAUNCH ALLIANCE

Mr. BRUNO. Thank you.

Chairman Rogers, Ranking Member Cooper, members of the committee, I appreciate the opportunity to come here today and talk about our ongoing transformation of ULA and our journey to replace the Russian RD–180 with an all-American solution for our rocket engine. As you know, we partnered with Blue Origin last year for the development of the BE–4 engine. It is a methane engine. It was 3½ years into its development. And the engine portion of that effort was fully funded, allowing us to move out smartly on that activity.

Rocket science is hard. And rocket engines are the hardest part. So prudence required that I also enter into a partnership with Aerojet Rocketdyne for the AR1 rocket engine as a backup. That is a kerosene engine. It is at present 16 months behind the Blue Origin 4 engine simply because it started later. And it does require significant government funding in order to continue. Both engines are currently on plan. They are meeting their project and technical milestones. And, most importantly for our Nation, both will bring the advanced engine cycle technology that is present on the RD–180 to American shores and allow us to regain our leadership in this key technical area.

Now, as we do all of this, ULA's focus will remain laser sharp on mission success and schedule certainty. We are very proud of our perfect, on-time successful record of now 96 consecutive launches, many of which were critical national security assets. Now, in order to do all of this and avoid an assured access gap and generate the commercial funds necessary for this investment in this new engine, it is necessary that we be allowed to continue competing with the Atlas launch vehicle in order to support those missions and provide the funds that are required to do this. And so I am grateful to the House and especially for this committee and the work that you have done to correct the situation that Ranking Member Cooper referred to that will allow us to have true and proper competition going forward while we protect our own national security.

Now, as we stand here today, the industry has matured to admit a second provider for national security launch. I think that is a good thing. Competition is healthy for the taxpayer, and it is healthy for the industry. I look forward to competing in this new environment. And I am confident that when there is a fair and even playing field, that ULA can come to that field, and we can win. So I am optimistic about the future of space launch. I am inspired by the missions that I have the privilege to be entrusted with. And I look forward to your questions.

[The prepared statement of Mr. Bruno can be found in the Appendix on page 63.]

Mr. ROGERS. Great. Thank you, Mr. Bruno.

Mr. Meyerson, you are recognized for 5 minutes.

STATEMENT OF ROBERT MEYERSON, PRESIDENT, BLUE ORIGIN

Mr. MEYERSON. Chairman Rogers, Ranking Member Cooper, and members of the subcommittee, thank you for the opportunity to speak before you today. Assured access to space is a national priority and a challenge that we must meet domestically. Blue Origin is working to deliver the American engine to maintain U.S. leadership in space and deliver critical national security capabilities.

Our partnership with ULA is fully funded and offers the fastest path to a domestic alternative to the Russian RD–180 without requiring taxpayer dollars. For more than a decade, we have steadily advanced our capabilities, flying five different rocket vehicles and developing multiple liquid rocket engines. We are spending our own money rather than taxpayer funds. And we are taking a clean sheet approach to development. As a result, we are able to outcompete the Russians, building modern American engines to serve multiple launch vehicles.

Our recent successes demonstrate that. In April of this year, our BE–3 engine performed flawlessly, powering our New Shepard space vehicle to the edge of space. The BE–3 is the first new American hydrogen engine to fly to space in more than a decade. United Launch Alliance recognized the merits of our approach when they selected our BE–4 for their Vulcan rocket. The BE–4 improves performance at a lower cost and is already more than 3 years into development. Most importantly, it is on schedule to be qualified in 2017 and ready for first flight on the Vulcan in 2019, 2 years ahead of any alternative.

Being available 2 years earlier means that there is 2 years less reliance on the Russians. As with any ox-rich [oxygen-rich] staged-combustion development, there are many technical challenges. Blue has made conscious decisions, design choices to mitigate risk. And we also have an extensive testing program underway, completing more than 60 staged-combustion tests and multiple hotfire tests on our powerpack to date. Full BE–4 engine testing is on track, on schedule to be completed or being conducted by the end of next year. And because we own our own test facilities, we can do this much faster. Blue is well capitalized, and significant private investment has been made in the facilities, equipment, and personnel needed to make the BE–4 a success.

The engine is fully funded primarily by Blue with support from ULA and does not require government funding to be successful. Instead of duplicating private efforts, the U.S. Government should focus its resources on developing the next generation of launch vehicles to meet national security requirements.

In conclusion, no new engine can simply be dropped into an existing launch vehicle. Launch vehicles have to be designed around their engines. And launch vehicle providers are the ones who are best able to decide what type of engine they need. Thank you.

And I look forward to your questions.

[The prepared statement of Mr. Meyerson can be found in the Appendix on page 79.]

Mr. ROGERS. Thank you, Mr. Meyerson.

Ms. Van Kleeck, you are recognized for 5 minutes.

STATEMENT OF JULIE A. VAN KLEECK, VICE PRESIDENT, ADVANCED SPACE AND LAUNCH SYSTEMS, AEROJET ROCKETDYNE

Ms. VAN KLEECK. Chairman Rogers, Ranking Member Cooper, and members of the subcommittee, it is a privilege to be here today to discuss this important national security issue.

Simply stated, we have an engine problem on the Atlas V rocket, the Nation's best and most versatile national security launch vehicle. It uses a Russian-made RD–180 booster engine. On behalf of Aerojet Rocketdyne and its 5,000 employees nationwide, I want to thank this committee for recognizing the problem and taking action.

It continues to be our position that the fastest, least risky, and lowest cost way to fix this problem is to develop an advanced American rocket booster engine to replace the Russian RD–180. With a focused competitive acquisition based on a robust public-private partnership, we firmly believe this can be accomplished by 2019. In fiscal years 2015 and 2016, this committee took a leadership role by authorizing funding and direction for the Air Force to competitively develop this engine by 2019.

Aerojet Rocketdyne welcomes the opportunity to compete for this effort for an engine that we call the AR1. Unfortunately, more than 6 months have passed since fiscal year 2015 funds were authorized and appropriated for the engine development program that this committee mandated. And virtually no money has been spent. It appears that this engine development is being subsumed into a lengthy new launch vehicle development and subsequent launch service acquisition.

Mr. Chairman, earlier this week, you stated in the press, and I quote, "It is not time to fund new launch vehicles or new infrastructure or rely on unproven technologies. It is time for the Pentagon to harness the power of the American industrial base and move with purpose and clarity in order to swiftly develop an American rocket propulsion system that ends our reliance on Russia as soon as possible," end quote.

You are exactly right. And we wholeheartedly agree with you. This is a national security imperative and should be treated as such. We have the technology to fix this problem, but we must get moving. For the focused public-private partnership, Aerojet Rocketdyne has the proven capability to develop a state-of-the-art, advanced-technology kerosene-fueled booster engine that can be certified by 2019 and be a near drop-in replacement for the Russian RD–180 on the existing Atlas V.

Aerojet Rocketdyne is able to say this with confidence based on more than 60 years of experience developing and producing launch vehicle propulsion. We have at hand these technologies as we have worked on them for the last 20 years. We have active state-of-the-art liquid rocket engine factories that are currently delivering engines supporting upcoming national security launches. We are the only domestic company that has designed, developed, produced, and flown rocket engines with thrust greater than 150,000 pounds thrust. Replacing the RD–180 requires nearly a million pounds of thrust. We have experience developing large liquid rocket engines on short timelines such as our Nation now faces. The R–68, the first-stage engine on the Delta 4 launch vehicle, which produces 700,000 pounds of thrust, was developed and produced on a 5-year schedule. AR1 will not be a copy of the RD–180. It will be a superior all-American engine and will leapfrog Russian technology. AR1 will be available to any U.S. launch booster propulsion user and configurable to any launch vehicle.

The engine's intellectual property will be retained by the government. To reiterate, our Nation has an engine problem on its premiere launch vehicle, the Atlas V. We must get rid of the Russian rocket engine. At Aerojet Rocketdyne, we believe the fastest, least risky, lowest cost manner to do this is to develop an advanced American engine to replace the RD–180 on Atlas V. This can only be done by 2019 with a focused and robust engine development program and a public-private partnership. Doing so will preserve access to space and reinvigorate the U.S. rocket propulsion industrial base.

Chairman Rogers, I want to thank you again for holding this important hearing. These are difficult issues. And each of us at the table has competing equities at stake. On behalf of Aerojet Rocketdyne, I appreciate you allowing our voice to be a part of this conversation. I look forward to your questions.

[The prepared statement of Ms. Van Kleeck can be found in the Appendix on page 86.]

Mr. ROGERS. Thank you, Ms. Van Kleeck.

Mr. Culbertson, you are recognized for 5 minutes.

STATEMENT OF FRANK CULBERTSON, JR., PRESIDENT OF SPACE SYSTEMS GROUP, ORBITAL ATK

Mr. CULBERTSON. Good morning, Chairman Rogers, Ranking Member Cooper, and members of the subcommittee. Thank you for the opportunity to appear today. I have submitted my full statement for the record, of course. And, in the interest of time, I will briefly describe for the committee how Orbital ATK is working to support the United States national security space systems and launch vehicle programs. As a global leader in aerospace and defense technologies, Orbital ATK designs, builds, and delivers affordable space, defense, and aviation-related systems to support our Nation's warfighters, as well as civil, government, and commercial customers in the U.S. and abroad.

Our company is the leading provider of small- and medium-class space launch vehicles for civil, military, and commercial missions, having conducted more than 80 launches of such vehicles for NASA [National Aeronautics and Space Administration], the U.S. Air Force, the Missile Defense Agency, and other government, commercial, and international customers in the last 25 years, including delivering approximately 4 tons of cargo to the International Space Station.

As the committee is aware, earlier this year, the U.S. Air Force announced its EELV Phase 2 development and launch services acquisition plan. One of the key components of this plan, beginning in fiscal year 2015, centers on the rocket propulsion [system] or RPS prototype program. We believe the Air Force's acquisition plan for RPS is well conceived and, if supported by Congress, will be successful in providing new space launch capabilities that are affordable, reliable, and available by the end of this decade. As both a launch vehicle builder and a propulsion system supplier, Orbital ATK is prepared to support the Air Force's RPS prototype program. Orbital ATK has proposed both solid and liquid propulsion system developments that will support a new, all-American launch vehicle family that meets all the specified national security launch requirements, as well as civil, government, commercial, and international launch needs.

It is true that we are currently using the Russian engine on one of our launch systems. That is because it was the only one available to us at the time. We had to meet our commitment to the International Space Station and deliver cargo. Our new systems, however, will be developed in a public-private partnership with significant private investment. And we are confident that our alternatives will be ready to support first flights by early 2019. Orbital ATK is committed to supporting our Nation's assured access to space policy. Reliable, affordable, and capable space launch systems are critical to ensuring our country is prepared to maintain access to space.

Through the program outlined by the Air Force, we believe that U.S. industry is able and poised to respond to this need and will provide the best possible combinations of systems for the future of U.S. access to space. We appreciate the efforts of this committee and this Congress to correct the situation we find ourselves in propulsion development in this country.

Thank you, Mr. Chairman. I look forward to your questions.

[The prepared statement of Mr. Culbertson can be found in the Appendix on page 103.]

Mr. ROGERS. Thank you, Mr. Culbertson.

Mr. Thornburg, you are recognized for 5 minutes.

STATEMENT OF JEFFERY THORNBURG, SENIOR DIRECTOR OF PROPULSION ENGINEERING, SPACEX

Mr. THORNBURG. Mr. Chairman, Ranking Member Cooper, members of the subcommittee, thank you for the opportunity to appear before this committee. In addition to my opening statement, I have prepared a detailed written statement, which I have submitted for the record.

Mr. Chairman, this country's ability to launch rockets without using Russian engines should not be in question. America right now has talented rocket scientists, engineers, and technicians currently flying or developing innovative, American-made solutions to end U.S. reliance on Russia today. It bears noting that there has been a concerted movement towards national consolidation of the Russian space industry and a series of recent failures with Russian rockets, engines, and spacecraft.

Having worked in this business for 20 years for both government and private industry, including the Air Force and NASA's Marshall Space Flight Center, I can tell you that more is happening now in propulsion development in the United States than at any time in my career.

What is SpaceX doing? SpaceX today is the largest private producer of liquid-fuel rocket engines in the world. The first stage Merlin engine has flown 162 times to space, more than any other domestic boost-phase rocket engine flying, including the RD–180 and the RS–68 combined. In the past 13 years, SpaceX has developed nine different rocket engines. Merlin is the first new American hydrocarbon rocket engine to be successfully developed and flown in the past 40 years, all while offering the highest thrust-to-weight ratio ever achieved.

We are investing in a next-generation rocket engine called Raptor, which will be a fundamental advancement in propulsion technology and serve a number of applications for the national security space market. And we have captured more than 50 percent of the global space launch market, unilaterally increasing U.S. market share from zero percent in 2012.

With respect to a national engine program, the Air Force is undertaking a strategy to result in not just a rocket engine but in launch systems. We believe this approach will, if done correctly, benefit the entire U.S. industrial base, properly require private industry co-investment, and meet requirements for U.S. Government launches. Most importantly, the Air Force is seeking to ensure that any new system is commercially viable in order to end the current practice of costly and unsustainable government subsidization.

SpaceX stands ready and able to provide access to space for the United States with our launch systems today, as well as next-generation propulsion launch systems. In May, the Air Force certified the Falcon 9 launch system to launch the most critical national security space payloads. We appreciate the Air Force's confidence. Powered by SpaceX's Merlin rocket engine, the Falcon 9 can perform 60 percent of the DOD [Department of Defense] launch requirements to date. We are also building, qualifying, and certifying the Falcon Heavy, which also uses the Merlin rocket engine. Between these two launch vehicle systems, SpaceX will be able to execute 100 percent of the DOD launch requirements and provide heavy-lift redundancy for the first time to the government. We anticipate Falcon Heavy certification in mid-2017. At the same time, SpaceX is developing Raptor. This staged-combustion reusable system will not only be extremely powerful but also versatile, efficient, and reliable while achieving commercial viability through notable risk and cost-reducing improvements. Raptor will advance the state of the art, ensure the U.S. remains the global leader in rocket propulsion technology, and serve important applications for national security space launch.

Importantly, meaningful competition is reentering the EELV program. With this, we have seen the incumbent make promises to reduce its costs, innovate, and fund new development efforts with private capital. These are good things. Much has been made of a so-called impending capability gap in assured access to space. The only gap that currently exists relates to heavy-lift capability. This is because the Russian-powered Atlas V does not have a heavy-lift variant. Otherwise, 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 4, are both made in America, certified for DOD launch.

The Atlas will continue to fly through 2020 under current law. Even if no engine or launch vehicle is flying by the congressionally mandated deadline of 2019, there will be no gap. Soon, however, the Falcon Heavy Launch System will close the preexisting gap in heavy-lift through internal funding by SpaceX. Falcon Heavy will be certified years before any proposed national engine program is set to fly. I want to close my testimony with some constructive solutions to truly achieve assured access.

First, the United States doesn't need more Russian engines to get national security space payloads to orbit. Second, continue working to achieve assured access through genuine competition between multiple qualified providers with redundant, truly dissimilar launch vehicle systems. Third, Congress must properly structure its engine development effort to maximize smart investment. Any government money should be matched at 50 percent by private capital to ensure meaningful co-investment. And commercial viability must be a key component of the future system.

Mr. Chairman, thank you. SpaceX, with our U.S.-built Falcon 9 and Falcon Heavy, as well as our investments in homegrown, next-generation propulsion systems like Raptor, looks forward to contributing to the Nation's space enterprise. I am pleased to address any questions you may have.

[The prepared statement of Mr. Thornburg can be found in the Appendix on page 113.]

Mr. ROGERS. Great. Great job. I thank all of you.

My first question was going to be to the companies, do you think you are capable of providing us a rocket propulsion system, an advanced rocket propulsion system that can replace the RD–180 by 2019? Mr. Meyerson and Ms. Van Kleeck both answered that in their opening statement.

Mr. Culbertson, I was interested in your opening statement, you implied that you all are going to get into competition for this replacement engine. Was that an accurate interpretation of your opening statement?

Mr. CULBERTSON. Yes, sir. We certainly are working towards that end.

Mr. ROGERS. Excellent.

Mr. Thornburg, are you all planning on getting in that competition for a replacement engine for the RD–180? And can you have it done by 2019?

Mr. THORNBURG. Through our existing launch vehicles with Falcon 9 and Falcon Heavy, we can provide 100 percent of the Nation's needs for national security space missions. In addition, we will continue our investment in next-generation propulsion systems and capability to further increase the U.S.'s position in propulsion development.

Mr. ROGERS. My understanding is you are talking about you can use your Falcon 9 1.1 and Falcon Heavy when it is certified to compete for this mission, but you are not planning to get in the competition to develop a propulsion system to fit on the Atlas V?

Mr. THORNBURG. We are investing internally in next-generation propulsion systems like Raptor. And we are happy to have the conversation about how we can support the U.S. Government. And any time the Congress and the U.S. Government asks, "what can industry provide to service the needs of the country," we are ready to participate in that conversation.

Mr. ROGERS. I heard you make reference to both the Merlin and the Raptor. If those, in fact, would work in some way with a launch system, would you be willing to sell those to other U.S. companies, launch companies?

Mr. THORNBURG. From an engineering standpoint, yes, that is something that we would entertain at SpaceX.

Mr. ROGERS. Mr. Culbertson, you wanted to be recognized?

Mr. CULBERTSON. Yes, sir. I am not sure I totally understood your question correctly. We are not proposing a replacement engine for Atlas. We are proposing a launch system that would meet the needs of the country in response to the Air Force——

Mr. ROGERS. Okay. That's what I thought. You had me excited for a minute there. I want a new engine. I don't want a new rocket. We want something to replace the RD–180 and if not be a drop-in fit on the Atlas V, something that doesn't require a whole lot of modifications to work on the Atlas V. I understand all of you all like what you have got. And I know Mr. Bruno wants a new rocket and a launch system. That is awesome, as long as we are not paying for it. We want an engine to be able to get our critical missions into space in a timely fashion. And 2019, as you know, is a critical time for us. I will now go back to the two people I know are going to compete for it, Mr. Meyerson and Ms. Van Kleeck. And we will start with Mr. Meyerson. Will the cost of your engine be comparable to what we are currently paying for the RD–180?

Mr. MEYERSON. According to our customer at ULA, we understand it is. It is comparable or better than what is being, the RD–180.

Mr. ROGERS. Ms. Van Kleeck.

Ms. VAN KLEECK. Yes, sir, we have designed the AR1 to be at or below the price point of the RD–180.

Mr. ROGERS. Okay. I want to stay with you, Ms. Van Kleeck, for a minute. Mr. Bruno, in his opening statement, made reference to the fact that you were 16 months behind Blue Origin in your development of your engine. Could you address that observation? And what does he mean by that?

Ms. VAN KLEECK. Well, I don't have my competitor's schedule, so I can't say for certain where the 16 months comes from. What I can say is we will be certified by 2019. We are very confident about that. We have spent 20 years developing this technology from the Russians, that was pioneered by the Russians. We have the factories. We have a schedule. We will be testing full-scale engines in the beginning of 2017. We will provide a full engine set to ULA in 2018. And we will complete certification in 2019.

Mr. ROGERS. 2018 or 2019?

Ms. VAN KLEECK. We will complete certification of the engine in 2019.

Mr. ROGERS. Mr. Meyerson, tell us what your schedule is. When do you think you will complete certification?

Mr. MEYERSON. We believe the engine will be qualified in 2017 and certified for flight on the Vulcan in 2019 or ready for the first flight on the Vulcan in 2019, with certification of the system coming after. We have been working at this for more than 3 years. And we have the facilities and the people and processes and equipment in place to do so. So we have high confidence in our schedule. We are testing hardware now. We are testing today. So the confidence, the level of data is well ahead of any alternative. So that is what gives us the confidence in our schedule.

Mr. ROGERS. Now, you made reference to the Vulcan in your opening statement. And I know Mr. Bruno really wants to have a Vulcan launch system.

Mr. MEYERSON. Yes.

Mr. ROGERS. We are interested in the Atlas or I am in my questioning. Will your engine work on the Atlas with modifications? And how significant a modification would it take?

Mr. MEYERSON. So our engine runs in liquid oxygen and liquified natural gas. So, no, as it is, as the Atlas is designed, it will not integrate with the Atlas.

Mr. ROGERS. We would have to have a new launch system?

Mr. MEYERSON. That is right.

Mr. ROGERS. Okay.

Mr. Bruno, let's talk about this Vulcan system. Tell me where that came from and when you see that happening and how does that play into what we are doing right now. Given, you know, our previous testimony and my comments publicly and our conversations privately, I feel very strongly, I just want a replacement for the RD–180. Why are we talking about the Vulcan?

Mr. BRUNO. Certainly. Well Vulcan really refers to a series of evolutions to the Atlas that takes several years to accomplish. The first step in that evolution is simply replacing the engine that is on the Atlas. So whether it is an AR1 or a BE–4, that Atlas with that new engine would be called Vulcan and it would still have the Atlas upper stage, Atlas fairings, Atlas strap-ons. It is essentially an Atlas with a new engine. If I might take a moment, I would like to expand on my colleagues' answers, I think they were far too modest when they responded to your question relative to the cost of their engines.

First, understanding that there is no such thing as an RD–180 drop-in replacement, we are not at this time capable of replicating the performance and the thrust level of the RD–180. What they are talking about is providing a pair of engines that would replace the single RD–180. That pair of engines we expect to be upwards of 35 percent less expensive than a single RD–180. So while the performance of the engine is only first generation and lagging what the RD–180 has, the manufacturing technology is a giant leap ahead.

Mr. ROGERS. I will get back to you all on my next round of questions. I want to turn to my friend now from Tennessee, the ranking member, for any questions he may have.

Mr. COOPER. Thank you. I appreciate the expertise on this panel. And I appreciate my friendship with the chairman. I am a little worried that we are pursuing a unicorn here because I think Mr. Bruno just said there is no such thing as a replacement for the RD–180 engine, there is no drop-in equivalent. And we are kind of fooling ourselves if we think there could be, at least in the reasonable future.

Now, there are some, you know, workarounds, replacements. And there is certainly new launch systems. So continuing the theme of my opening statement, I think our first role should be, "first, do no harm," because we wouldn't even be here if we had gotten the language right in last year's NDAA. So I am not a technical expert. I am certainly not a rocket scientist. But it seems to be that in this testimony there are some remarkable differences.

First of all, I regret, it is a little bit unfair, the witnesses are at least three to one against SpaceX. And I am not sure that is fair. Perhaps we should have given Mr. Thornburg three times the time. It may be three and a half to one against, but he more than held his own. And it should be exciting for all Americans that we have billionaires and entrepreneurs who are willing to devote so much of their resources to coming up with new and apparently more efficient solutions.

But the factual question, is there a gap? It seems to me that we need at least 9 RD–180s. We may need 29. We may need more than 29. And, meanwhile, a lot of what you hear on the Hill is a lot of bad-mouthing of the Russians. And there is plenty of reason to bad-mouth at least their leaders. But while we are dependent on the RD–180, it may not be the smartest thing strategically to bad-mouth the source.

Hopefully, we can overcome this gap. And Mr. Thornburg's testimony is that the real gap is the premature decision to retire the Delta Medium. So there you don't blame the Russians, you blame us. Or the gap could be the Air Force dragging their feet to certify the new Falcon Heavy. And certainly there are a lot of worthy and important requirements and certification, three required successful launches, lots of things. I loved Mr. Culbertson's quote of Wernher von Braun when he said: We can lick gravity, but sometimes the paperwork is overwhelming. What Congress is really good at is paperwork and putting in artificial requirements that oftentimes impede the private sector's ability to innovate.

I get worried that when it comes to a drop-in engine, you are talking about my beloved old Chevrolet Impala and trying to find a new V–8 to put in the old vehicle. I want a car that will work, not just an engine that will perform. And when we talk about assured access to space, we want a vehicle that can get our payloads up into the appropriate orbit. And it may be that we haven't had enough discussion on this panel of appropriate orbits, and maybe we can't do that in an open setting. But we have to serve all of our national security needs. And some of those are harder to achieve than others.

So I hope that this hearing, and it may take the second panel to do it, will be able to resolve the question of whether there is a gap and, if so, how large, and how best to bridge that gap. And to a certain extent, all of the witnesses are asking us to buy some vaporware because nobody can predict, nobody has a perfect crystal ball. One tends to believe in Mr. Bruno when he says really, getting realistic, ain't going to happen before 2021, 2023, maybe because it takes time, at least the American way of doing it. I hope it is not that long. And we should all be encouraged with the new methane engine, the Blue Origin is completely amazing. But also the idea of the Raptor is totally amazing. But some existing accomplishments are things we should be deeply proud of.

I am a little bit worried about Mr. Thornburg's methodology because the Falcon uses 9 or 10 engines. And you claim an engine heritage that is able to be multiplied due to the number of engines. It makes me think that if the Falcon 9 were composed of 100 engines, then you would have a track record 10 times or 100 times more successful than all the RD–180s. That is, perhaps, a specious methodology for coming up with a track record. But still you can't deny the accomplishments because you have exceeded what most people would have expected. But, again, our job here is to not stand in the way of progress. And I think the statement of administration policy was pretty on point when it said so often the congressional language, especially last year's section 1608, gets in the way.

So how do we resolve this in a sensible way? We want commercial competition. We want assured access to space. But, above all, we have to have assured access to space. So I am hopeful that the witnesses can help us resolve these questions. And, as I say, it make take the second panel, but there seems to be general consensus that no one is talking about a drop-in engine. Because it is my understanding that even the proposed solutions are either 18 inches too long or 4 inches too long or there are really two engines instead of one engine. So the chairman's goal, as worthy as it may be, is really not available from any of the witnesses on this panel. Now, the chairman's goal of cost savings is extremely important. But I don't need to remind members of the Armed Services Committee how much money we are wasting on various things here or there. And in the scheme of things, the money we are talking about here is relatively small and manageable. The key is assured access to space.

So if any of the witnesses want to correct my impressions, I spent much of last night reading your testimony. It was very helpful. But it also is so conflicting, it is hard to find where the truth lies. So I hope—Ms. Van Kleeck, you seem poised.

Ms. VAN KLEECK. Yes, yes, sir, thank you for the opportunity. Rockets have been re-engined in the past, okay, on numerous occasions both in this country and others. There is, you can replace rocket engines. The AR1 is a near drop-in replacement. It uses——

Mr. COOPER. The AR1 is——

Ms. VAN KLEECK. Yes. And I will explain the differences. And they are minor. There is, we can reproduce an RD–180 in this country. It would cost, in my opinion, more money than it would to develop a new engine. It is a very complex engine. It would also cost a lot from a recurring standpoint. And I think it is time for the U.S. to leapfrog that technology anyway.

The AR1 uses the same propellant. It has the same engine cycle, so it has a very similar environment. It would use the same tankage, would have the same attach points, has the same performance, not lower performance, the same performance. It is two engines. We did look at making it a single engine. But two engines is probably a better long-term solution for the U.S. because it can be used in multiple other applications in the future. And you can have the exact same physical attach points with the two-engine solution, so really where the propellant feeds the engines and how it attaches. It is 11 inches longer. But we have been told by ULA engineers that the length is not an issue; there is length to work with. That will affect minor ground support equipment but it is very minor. We are talking modest modifications, things that we have done in the past. So it is as near to a drop-in replacement as can be made.

Mr. COOPER. But there are many other issues, acoustics. You know, and Mr. Bruno was saying just because you started late, you are 16 months behind. So we don't know what they will choose in the down select a year or two from now.

Ms. VAN KLEECK. Yes, sir. That is a fact. The acoustics, every rocket engine has a specific signature. The fact that it is the same cycle, runs at a very similar operating point, we would anticipate that would be similar.

Mr. COOPER. But there have been lots of anticipations that didn't necessarily pan out. And for assured access to space, we need something that will work.

Ms. VAN KLEECK. Yes, sir. But we have been a part of re-engining numerous launch vehicles over time. And we have been successful with those re-enginings. This engine has been designed from the beginning to be a replacement to Atlas V. Because we saw this problem coming 10 years ago. And we have focused on that. We understand the Atlas V very well. This engine was designed to interface with the Atlas V.

Mr. COOPER. Well, you may have seen the problem 10 years ago, but you are 16 months behind right now, even Blue Origin and some of these other things. So what, that puts us in a tough spot. We have to measure the gap and figure out how to fill the gap.

Ms. VAN KLEECK. You know, whether we are, again, we feel we can meet 2019, whether we are 16 months behind or not, we would, one would have to look at the details of these schedules and the different milestones to really come to that. I have not seen that.

Mr. COOPER. Mr. Chairman, I think my time has more than expired. Thank you, sir.

Mr. ROGERS. I thank the gentleman.

The Chair now recognizes the gentleman from Oklahoma, Mr. Bridenstine, for 5 minutes.

Mr. BRIDENSTINE. Thank you, Mr. Chairman.

One of the concerns I have is when you consider the House's position and the Senate's position on RD–180s, our positions are different. And I have heard that ULA is interested in developing the Vulcan to the extent that they have a certain number of RD–180s available for the future. And if we don't have that certain number, then they are not interested in developing the Vulcan.

My question for you, Mr. Bruno, is what happens if the Senate doesn't come the direction of the House? In that case, what happens to the Vulcan and what is your backup plan?

Mr. BRUNO. So either engine path that has just been discussed requires significant investment on the part of ULA. Without the continued revenue generation of the Atlas, until that new American engine is available, we will lack the funds to be able to accomplish that activity. Without that, we are entering into a marketplace where the Air Force market has declined and is incapable of supporting two providers.

Now, the good news is the overall lift market is large enough to support both of us, both the new entrant and us and the other traditional suppliers. But in order to be a viable economic entity in that environment, we need to be able to effectively compete for civil and commercial missions in addition to competing for national security space missions. Without that lower-cost rocket and without the investment required to get there, we are simply not economically viable in that window.

Mr. BRIDENSTINE. You indicated that with the commercial launches in addition to the military launches that there would be economic viability for multiple providers. And it looks like even, you know, we might get a third provider with Orbital ATK potentially participating. That being the case, is there a reason ULA couldn't get private capital to support the investment?

Mr. BRUNO. It is unlikely that the capital markets would look at this uncertain investment environment any more favorably than our parents do. So investment really dislikes and avoids uncertainty. And as we sit here today, it is very uncertain whether the Atlas will even be available to fly during the period between the end of its current contracts and the availability of the new rocket engine. So that leaves a multiyear period of time when we have no product to bring to the marketplace. Not very likely I could attract money from capital markets for that.

Mr. BRIDENSTINE. Mr. Culbertson, does Orbital ATK agree with that position, that it is not worth the investment if there is not more RD–180 engines? Obviously, you guys are doing it without the RD–180 engine.

Mr. CULBERTSON. I can't really comment on ULA's position on this. We do see a market out there, but it is still pretty slim in the classes we are discussing here. We actually are working with ULA to continue to supply cargo to the International Space Station. After we had the accident, they, SpaceX, and a couple other companies stepped forward and said: We can give you a ride.

And we have contracted with them on a commercial basis to do that. So we are sort of the beginning of their commercial market to continue to fly. But we also are continuing to develop our own systems to fly not only to the space station, but to fly national security missions.

Mr. BRIDENSTINE. Mr. Thornburg, when you think about the commercial market with the EELV program, is the market big enough? And for how many providers? And, clearly, you guys are already making the investment privately.

Mr. THORNBURG. Correct. And I would also say, you know, that as an engineer, I am not necessarily studying the markets. But I can say that SpaceX believes there is, that we can be very competitive across the market. As I mentioned in my opening statement, we have recaptured for the United States 50 percent of the launch market share. So certainly with more cost-effective launch solutions, the market does open up.

Mr. BRIDENSTINE. And for Mr. Bruno, you would know that the United States and we, as Members of Congress, we want to make sure we have assured access to space which means we need multiple launch service providers for the EELV program. That being the case, your investors have got to understand that it is not in our interest as a Nation to have two providers and one of them go out of business and end up with a monopoly, which means there is going to be some level of security, would you agree with that? And are your investors, your parents, aware of that?

Mr. BRUNO. The only data I have to operate on at the moment is the forecasts that the government has provided for the space lift that occurs in that window of time. And it is important to remember that we are the ride for national security assets. They are recapitalized in waves. So we are currently recapitalizing a set of national security satellites that are well past their design life. That is going to complete in a short number of years. There will be a long trough until the new assets run out of life, and then they will be recapitalized. So it is very cyclic. What has been forecasted to us by the government—and it is a pretty sound forecast because we can see the satellites in the pipeline being designed and built—is that that marketplace drops from about 8 to 10 a year to 5. And then that will be divided between at least two providers, so two or three. And that is not a sustainable economic model if you do not also have access to civil and commercial markets.

Mr. BRIDENSTINE. Okay.

Mr. Chairman, I yield back.

Mr. ROGERS. Thank you very much.

The Chair now recognizes the gentleman from Colorado, Mr. Coffman, for 5 minutes.

Mr. COFFMAN. Thank you, Mr. Chairman.

First, Mr. Bruno, congratulations for an outstanding record of success. Jeff Bezos, founder of Blue Origin and Amazon, said, quote, “ULA has put a satellite into orbit almost every month for the past 8 years. They are the most reliable launch provider in history. And their record of success is astonishing,” unquote. I am proud that ULA is headquartered in Colorado. I am fully confident ULA will remain very competitive in the future. You enjoyed an exclusive contract because of your competence. But I want to ask you what exactly can Congress do to ensure that across the board we have created an environment that promotes innovation while not unfairly tipping the playing field towards or away from any potential provider.

Mr. BRUNO. Certainly. But, first, I have to observe that that comment reveals that Mr. Bezos is obviously a very intelligent man. So in order to have a fair and even competitive playing field that is healthy and in the interest of the government and good for industry, it is important, of course, that the participants in that competition are able to bring competitive products to the marketplace. That is why we need continued access to Atlas.

In addition to that, the competition itself needs to be fair and even. So we must be held to the same technical standards in terms of the performance and the missions that we are able to fly, as well as the contracting requirements. So, today, the ULA is required to perform to what is called FAR [Federal Acquisition Regulation] Part 15, which are a set of very complex and sophisticated acquisition regulations. They require for us to provide elaborate, extensive, and expensive financial recording, tracking, and reporting systems.

Our competitor in a commercial marketplace does not. So all of these elements have to be leveled. And then I would also advise the government that for national security missions, for which our Nation's safety depends and warfighters' lives are at risk, that a low-price, technically acceptable, type of priced shootout is not an appropriate methodology. You wouldn't buy your car that way. You wouldn't buy your home that way. And our soldiers' lives should not be dependent upon it. So when competing and when making selections, they should consider cost equally balanced with technical performance, reliability, and schedule certainty. Remember, I mentioned that the assets being recapitalized are generally beyond their design life. There is an urgency to replacing them as soon as possible. That, too, should be considered.

Mr. COFFMAN. Thank you.

Mr. Thornburg, congratulations on the successful certification of Falcon 9. In March, Ms. Shotwell testified in this committee that you have DCAA [Defense Contract Audit Agency] auditors doing manufacturing audits right now, and your cost and your rates have been audited. Was that testimony correct? And can you briefly describe the frequency and extent of the DCAA audits that SpaceX undergoes and the number of DCAA personnel resident at SpaceX facilities?

Mr. THORNBURG. To your first question, was her testimony correct, yes, the answer to that is yes. With regard to the questions about DCAA audit and frequency, in my position within engineering and working engine and vehicle development, I am not familiar with the frequency of the visits. I can tell you that we are working very closely with the Air Force and the DOD. I would be happy to go collect that information and return it for the record.

Mr. COFFMAN. I would really appreciate if you could get that back to us for the record.

Mr. Chairman, I yield back.

[The information referred to can be found in the Appendix on page 168.]

Mr. ROGERS. I thank the gentleman.

The Chair now recognizes the gentleman from Colorado, Mr. Lamborn, for 5 minutes.

Mr. LAMBORN. Thank you, Mr. Chairman, for having this very important hearing. And thank you for the timeliness of this hearing.

Mr. Thornburg, I would like to ask you about the current version of the Merlin engine that you are using. Is it the new, is the new baseline, is the full thrust Merlin engine the new baseline for the Falcon version 1.1 going forward? And does SpaceX intend to bid that system for upcoming EELV launches?

Mr. THORNBURG. The current engine we are flying is the Merlin 1D boost engine. Your reference to the full thrust is a minor upgrade to that engine that basically takes the full potential of that engine system for future missions on the Falcon 9 1.1.

Mr. LAMBORN. Now, what are the differences between the two systems, both hardware and software? I heard there are hundreds of differences. Is that correct?

Mr. THORNBURG. I can't recall the exact number of differences. I can say that from a technical standpoint engineering-wise, the differences are very minor in terms of the changes in the upgrades to the engine. It is all in line with our continual improvement of our propulsion systems and overall vehicle systems. But, essentially, we are taking the existing Merlin 1D with its present design and performance and taking the additional performance that we have available there and offering it to our customers to enhance the performance of the Falcon 9 1.1 system.

Mr. LAMBORN. But what I am trying to get at is with the changes that you have incorporated, does the previous certification cover the new, what amounts to what I would consider a new version once you have started making a lot of changes?

Mr. THORNBURG. As far as the certification effort to date, the recent certification of the Falcon 9, the Merlin 1D engine now and going forward, the bulk of that is identical. So we are talking about minor changes and upgrades to the system that will be reviewed through ongoing and future Engineering Review Board activity with the Air Force.

Mr. LAMBORN. So even though there are an undetermined number of changes, indeterminate number of changes, you can't give a number, you don't think that amounts to anything worth recertifying?

Mr. THORNBURG. No.

Mr. LAMBORN. Or reopening the——

Mr. THORNBURG. No. And I can comment that the ongoing dialogue with the Air Force through the certification process has been fantastic. We are working very closely with the Air Force as well as the Aerospace Corporation. The type of improvements and modifications that the Falcon 9 launch vehicle is going through now is no different than improvements that Atlas and Delta have taken on over the years. So we are in line with that in terms of the initial certification and then ongoing certification activities as these improvements come online.

Mr. LAMBORN. Okay. I just wish there was a little more certainty in this. Because you can't even tell me how many changes there are. I guess that is a concern I think we should get to the bottom of.

Changing gears here, Ms. Van Kleeck, what advanced technology does the RD–180 use? And why isn't it important that we bring that technology to the U.S.?

Ms. VAN KLEECK. Well, the RD–180 is what is called an ox-rich [oxygen-rich] staged-combustion engine. It is a closed-cycle engine which, closed-cycle engines are the most efficient engines that can be, chemical rockets that can be produced. The RS–25 that powered the space shuttle was also one of these engines. The Russians pioneered and perfected the ox-rich staged-combustion engine during the Cold War. And the U.S. didn't. The U.S. perfected solids and hydrogen systems. It is a very high-performing, hydrocarbon engine. It provided a lot of advantage to the original Atlas vehicle. Some of the things that are in it are advanced coatings, advanced materials. It is very compact, very high pressure. Those are things, particularly the materials, were things that this country did not choose to pursue and didn't develop. And so that is where the—there is a technology gap in this particular variant of rocket engines in this country.

Mr. LAMBORN. Mr. Meyerson, do you agree with that assessment?

Mr. MEYERSON. In terms of the RD–180 and the importance and the efficiency of the cycle, yes, I agree. I think, you know, if you look back to the time that Lockheed Martin, ULA's parent, and the choice of the RD–180 was an enabler for the Atlas V. That Atlas V rocket would not have worked without the RD–180. Today, I think it is time to take a fresh look and look at a new engine. The ox-rich staged-combustion cycle is critical. And that is what Blue Origin has chosen for the BE–4. But the BE–4 is the enabler for the next generation of American launch vehicles. And it is—the choice of methane, liquified natural gas, as the propellant is one of those enablers.

Mr. LAMBORN. Okay. Thank you.

And thank you all for being here.

Mr. ROGERS. I thank the gentleman. I will start our second round of questions. I was listening to my buddy from Tennessee when he was talking about his Chevy and dropping a new engine in and how sometimes that wasn't all that easy because, you know, I made it very clear, my priority is to re-engine the Atlas V. And it just reminded me as he was talking, he and I had the true privilege to meet with an American treasure earlier this week, retired General Tom Stafford, also an Apollo astronaut. And we both visited this topic with him, you know, how big a deal is this to re-engine this rocket? And he basically said: It is nothing. We re-engined fighter jets for generations. And that is much more complicated than what we are talking about here.

And so, with that backdrop, Mr. Culbertson, your company is in the process of changing the engine in the Antares launch vehicle from the NK–33 to the RD–181 Russian engine, is that correct?

Mr. CULBERTSON. Yes, sir.

Mr. ROGERS. Considering your current experience, how reasonable is it to change an engine to an existing launch vehicle?

Mr. CULBERTSON. It depends on the background of the engine and what it was originally designed for and the maturity of it at the time that you move forward with it.

The engine that we are using in the future generation of Antares launch vehicles, which we intend to start flying next year, was specifically designed as a replacement for the NK–33, which the AJ–26 was based on. So the arrangement of the thrust vector, the piping, if you will, for the fuel systems, the connections, the size of the engine, and the thrust levels were all very comparable to the NK–33 because it had been in development for almost 10 years now to replace that engine on a couple of different Russian rockets. So when we started talking to them over 3 years ago, they were pretty far along on that path already. We did a lot of analysis to make sure that it would, in fact, be compatible. And when we reached the point where we needed to move forward with another engine, it was the one that was most likely to succeed in our application and the one that was available to ensure we could continue to deliver cargo.

Mr. ROGERS. Great. Ms. Van Kleeck, you have already heard some reference to it today in the interchange with the ranking member, and in the next panel, we are going to hear that it is going to cost a significant amount of money to re-engine the Atlas V with the AR1. Can you address where 200—and as I understand it, you are going to hear it is going to cost at least $200 million to modify the Atlas V for the AR1. Can you address that?

Ms. VAN KLEECK. Yes, I can. We have been working closely with ULA for several years now on replacing an RD–180 in various forms. Like I said, we have looked at this problem over the past 10 years. We have an active contract right now identifying the specific changes that need to be made, assuming this goes into an Atlas V vehicle. We are also looking at a Vulcan configuration. That configuration requires a different launch vehicle. Relative to the Atlas, I have summarized the changes that need to be made, and I will submit those for the record.

[The information referred to can be found in the Appendix on page 167.]

Ms. VAN KLEECK. In terms of the estimate for those costs, I have heard a variety of numbers. I have never heard a $200 million number. A number I have heard for the changes associated with an AR1 going into an Atlas V, are low tens of millions of dollars. I think that cost estimate is—still needs to be refined, but the type of modifications that are required are very minor.

Mr. ROGERS. For the AR1?

Ms. VAN KLEECK. For the AR1 to fit on the Atlas V vehicle. Yes, sir.

Mr. ROGERS. Okay. Mr. Meyerson, same question.

Mr. MEYERSON. Well, can I add to Mr. Culbertson's comment, his response? The key word was that 10 years of investment by the Russian government to develop a replacement for the NK–33, which was developed into the AJ–26, that is the key point. Ten years, and we don't know how much money was invested. The BE–4 is being developed. It is fully funded. We are more than 3 years into development. So this engine is real. There is real hardware to see. It is not a paper engine.

Mr. ROGERS. Great. Tell me, Mr. Bruno has stated that both the BE–4 and the AR1 would work on the Atlas V with modifications. One with more modifications than the other. Can you describe the extent to which we would have to modify the Atlas V for your engine to work?

Mr. MEYERSON. I think that is a better question for Mr. Bruno. But the engine, when you are developing a new engine, you start with requirements, and the details really matter. Because the BE–4 is so far along in its development, those details are much more well understood so that Mr. Bruno's team at ULA can look at that and design the right system to meet the national security need.

Mr. ROGERS. Mr. Bruno, I would love for you to visit this topic.

Mr. BRUNO. Well, this is an excellent sort of example of the difference between an engine provider and a launch vehicle service provider. It will not cost tens of millions of dollars to incorporate any version of an AR1. Recall that we started with an understanding that the performance level coming out of either of these two engines will not match the RD–180, and we will be using a pair of engines to do that. The thrust level——

Mr. ROGERS. Let me stop you there. Will the combined thrust of the two engines be comparable to the RD–180?

Mr. BRUNO. Yes, it will. In fact, it will be larger than the two.

Mr. ROGERS. Okay.

Mr. BRUNO. In addition to that, the RD–180 uses a very novel thrust vector control system to move the nozzle and steer the rocket based on fluidics that tap off the engine fuel system. That is also a technology that does not exist in the United States, and, by the way, one that we do not have an interest in developing. So there will be a new thrust vector control system to go along with that. So when we do all of that, with the new performance point that is required and the new thrust levels that will be delivered, there will be software changes; there will be structure changes; there will be alterations to the pad to accomplish even the AR1. The number that was quoted was not unreasonable, but I think you will hear from——

Mr. ROGERS. $200 million, I think, we are going to hear from the Air Force later.

Mr. BRUNO. Right.

Mr. ROGERS. Do you think that's an accurate?

Mr. BRUNO. I do think that's an accurate.

Mr. ROGERS. That is for the AR1?

Mr. BRUNO. That is for the AR1. I can drive that number down if I am willing to leave the tank exactly the same size that I have on Atlas. But if I do that, because of the lower efficiency of that engine and its first generation as a launch system for several missions, I will be adding one or more solid rocket boosters to the launch vehicle. And so the cost competitiveness, the affordability of that system, will be less than the Atlas today.

Mr. ROGERS. So getting you those modifications moves you towards the new rocket system you want, but is not necessary for the replacement engine that we are pursuing, or that I am pursuing?

Mr. BRUNO. It will not lift the same missions. So I think you are asking me, could I keep the tank size the same, take the engine that I am—that is made available to me, strap on the extra strap-ons and just deal with the additional cost. I could do that for the first set within the fleet. So remember that the Atlas is a fleet of rockets, the least capable of which is equivalent to a Falcon. There are much more difficult orbits that we go to. Eventually, there is a limit to how many strap-ons I can physically attach to the rocket because of the way the rocket is configured. Those most difficult missions would suddenly become out of reach of an Atlas in this configuration without a longer tank to carry more fuel.

Mr. ROGERS. Okay. Now that is the AR1 we are talking about. Let us talk about the BE–4.

Mr. BRUNO. Yes. So the BE–4 requires more extensive changes to our infrastructure and to our rocket.

Mr. ROGERS. So what the does $200 million figure turn into with the BE–4 as the down-selected engine?

Mr. BRUNO. It would not be unreasonable to triple or quadruple that number.

Mr. ROGERS. So $600 to $800 million?

Mr. BRUNO. Yes.

Mr. ROGERS. Okay. Let's talk about the other infrastructure involved when we change—let's say we do change to a new rocket. And I am not saying I am ready to go there, but what else is required for the launch? I mean, modifications other than just the rocket. Don't you have to change the infrastructure that you use for the launch process?

Mr. BRUNO. Yes. So, you know, you can think of it in these pieces: there is the rocket; there is the pad; factory, of course, with its tooling; and then the equipment that we use actually at the launch site to integrate the rocket with the satellite and roll it out.

So those things, you know, are more dependent upon the physical size and configuration of what changes we have to make to accommodate the engine. So my colleague is correct, there are far fewer changes with the AR1, because it is the same propellant, and so the diameter and the length of the rocket will be much more similar, much more of the tooling in the factory can be the same. The equipment at the launch pad can be only slightly modified and the pad will have smaller modifications.

For the methane engine, because methane is less dense, the tank will be much larger. I will have to replace much more tooling in the factory. I will have to redo what is called the mobile launch platform that moves the rocket to the pad, and then the changes to the pad are more extensive.

Mr. ROGERS. Are those costs a part of the tripling or quadrupling?

Mr. BRUNO. Yes.

Mr. ROGERS. So that was a comprehensive figure.

Maybe I missed it, but were you able to explain the difference in the 16 months of lead that you assert the Blue Origin has over Aerojet in their development?

Mr. BRUNO. Yes. So both companies are under contract with us. We have, you know, sort of weekly engagements, monthly formal program reviews. We are tracking both schedules side by side. As I mentioned in my opening remarks, Aerojet Rocketdyne started several years later than Blue Origin, and that is essentially the nature of the 16 months.

Mr. ROGERS. Okay. Thank you. This would be for all the witnesses. Do you agree that the government should own the intellectual property of any investment it makes in a new propulsion system?

Mr. Meyerson, I know you are talking about your private money. But if we are going to invest money in it, do you believe that we should own some of the intellectual value?

Mr. MEYERSON. I think if the government fully invested in the system, they should own the IP, yes.

Mr. ROGERS. Ms. Van Kleeck.

Ms. VAN KLEECK. Yes, sir. I do agree.

Mr. ROGERS. Mr. Culbertson.

Mr. CULBERTSON. Yes, sir. If the government has invested a majority of the money, then they should, as the law allows, own the IP for it. But the companies also investing should own their IP that they develop to enable the systems.

Mr. ROGERS. Mr. Thornburg.

Mr. THORNBURG. I agree with my colleagues in that if the government fully invests, then they would own and retain the IP rights. But for systems that are privately developed, they would not.

Mr. ROGERS. Now, I am a recovering attorney, so two of you used the term fully invest, Mr. Meyerson and Mr. Thornburg.

What if we paid for 60 percent of the development cost, is that something that you believe should inhibit our owning a percentage of the intellectual property's value? Let's start with Mr. Thornburg.

Mr. THORNBURG. I think it would depend on what type of development we were talking about in terms of the technology. If the technology was an offshoot of something that had been completely developed and invested by the private corporation, maybe not. But I think it would be case dependent.

Mr. ROGERS. Mr. Meyerson.

Mr. MEYERSON. I think the contracting methods, there is public-private partnerships, and there are mechanisms that can be in place to allow industry to invest and account for shared ownership.

Mr. ROGERS. That is one of my concerns. We have already set aside a little over $400 million for this, and we project that by the time it is all said and done, $1.3- to $1.5 billion is going to be spent in pursuit of this new engine, and as much as $800 million or more may be paid for by the Federal Government. So it just seems to me that there should be some interest that we have in the intellectual property that arises out of that.

I want to ask the witnesses this, and this is for all the witnesses: Are there clear requirements from the Air Force as we go into this process about what they are expecting, and do you think they are not only clear, but fair and reasonable?

Mr. Meyerson.

Mr. MEYERSON. I think—yeah, I think that the requirements are clear. Yes.

Mr. ROGERS. Ms. Van Kleeck.

Ms. VAN KLEECK. I assume you are referencing the current acquisition process that is underway?

Mr. ROGERS. Yes, ma'am.

Ms. VAN KLEECK. Yeah. And there is a—there is a process that is well spelled out in that. It does focus more on an ultimate launch service as opposed to an engine, but it is spelled out. I think there is a lot of different paths that that particular process can go.

Mr. ROGERS. Mr. Culbertson. I am sorry.

Mr. CULBERTSON. Yes, sir. We do feel like, based on our experience in both the commercial and the government market, we understand the requirements of the Air Force and what they are looking for, and we do think it is focused on a system that could be developed in a public-private partnership that would give the government the most options for competition as well as success.

Mr. ROGERS. Mr. Thornburg.

Mr. THORNBURG. With regards to the ongoing source selection activity, I don't think it is appropriate for me to comment on that right now, because I wouldn't want to say anything that would undo—unduly influence that ongoing source selection.

Mr. ROGERS. Mr. Bruno, do you have any comment on this? You are not building an engine, but you are going to be buying it.

Mr. BRUNO. I believe the requirements in the RPS activity that you are referring to are very clear from the government.

Mr. ROGERS. Are they fair and reasonable?

Mr. BRUNO. Yes.

Mr. ROGERS. Great. A couple of cleanup questions. This is for Ms. Van Kleeck. Your history is partnering with launch service providers or being a launch service prime when developing a new engine. Why do you believe that this approach is not appropriate in this situation?

Ms. VAN KLEECK. I think the issue at hand that we are talking about is replacing an engine. And right now we are looking at an acquisition process that is looking at replacing a service or looking at an evolution of that service. I believe with that acquisition you can get to an engine through that process, but it isn't the most efficient way to do that.

Mr. ROGERS. Okay. And then finally, Mr. Bruno. As ULA moves forward with a new Vulcan launch vehicle, can you tell the committee if you intend to mitigate your risk by carrying forward both the AR1 and BE–4 as design options? If not, why not? And if yes, when will you be able to require—be able to down select a new single option?

Mr. BRUNO. I will not carry them all the way until completion. We will carry both until it is clear that the major technical risk with either path has been retired and we are in a position to make a down selection based on their technical feasibility, their schedule, and their forecast of recurring cost. I expect that to happen at the end of 2016. The reason we will down select and not carry both forward is simply because I cannot afford to carry both all the way.

Mr. ROGERS. Great. Thank you very much.

The ranking member is recognized for any additional questions he may have.

Mr. COOPER. Thank you, Mr. Chairman.

There are 5 areas I would like to pursue. Some are just context and peripheral, but I think it is going to be important for this committee to understand.

In the Air Force RPS, is there a prediction in the out-years of payload size? Because I think the assumption is they are going to get—stay about the same size as they are today, some large and some small. There is some trends—if we're going to Mars, probably need to be on the big side. If we are going to do CUBESATs [miniaturized satellites], maybe we don't need the lift capability. So all this talk about launch systems and lift capacity, the question is, what are we lifting? And as electronics get smaller and smaller, it could be that lighter lift capacity is sufficient to do the job. I don't know the answer to that question. Anybody have any answers on this panel?

Mr. BRUNO. The standard reference for technical performance remains what the Air Force calls the 8 reference missions. And so they provide us with a set of orbits and payload weight to be lifted to that orbit. Those have not changed as of this date. The most challenging of those orbits require our complete capability all the way to the Atlas V with its 5 strap-ons and its largest payload fairing.

Mr. COOPER. Part of it is orbit, part of it is weight?

Mr. BRUNO. Yes. And it is probably important to understand the subtlety within that as well, which is the time required in space to reach the highest orbits, and that dictates some of the technical characteristics of the upper stage. So when we go to, for example, geosynchronous orbit, if you wish to directly inject, which the government generally does to preserve the life of the satellite, it takes 8 hours flying in space operating in upper stage in order to circularize that orbit, something not possible with conventional fuels like kerosene, for example, without elaborate systems to keep them from simply freezing up.

Mr. COOPER. Yeah. We haven't given much attention at all to the second-stage problems. And what you point out are very, very important. On the intellectual property issue, it is the greatest source of wealth on the planet, but we have increasing difficulty understanding ownership and relationships like that. I guess it gives us some comfort that an American citizen might be owning all this IP, but sometimes citizens move. Sometimes they make private sale decisions that could endanger a national security. So this is something that we need to figure out better. And in terms of payback to the taxpayers, if we could get one or two pharmaceutical companies to pay back all the benefits of their blockbuster drugs from basic research done at NIH, it would return many more than a few billion dollars. So perhaps we need to work with our colleagues on other committees on that.

On the question of paperwork, Mr. Bruno mentioned FAR 15, I think you called it. And that is a requirement that you have to endure, but some others might not. But I am not sure, is all of FAR 15 really good paperwork? Is that necessary paperwork? Can we streamline FAR 15 so that we can reduce the burden for anybody who might have to be subjected to all that paperwork burden? It is not the 10 Commandments. It is not written in stone.

Mr. BRUNO. The Federal Acquisition Regulations actually provide for different models; 15 is one set. There is another set referred to as 12, and there are others that do exactly that and provide guidance when it is appropriate to use the less-elaborate systems.

Mr. COOPER. So there is some flexibility within that. Is FAR 15 the biggest and scariest monster out there?

Mr. BRUNO. Yes.

Mr. COOPER. But there are lesser monsters? Okay. So you just mentioned that to scare us.

Mr. BRUNO. It happens to be the world that we live in at ULA.

Mr. COOPER. A question Mr. Bridenstine mentioned, monopoly. Nobody likes monopoly, but I think in the best case situation we would have a duopoly or maybe an oligopoly. We need to find another billionaire to back Ms. Van Kleeck here. Where is Richard Branson when we need him? Or maybe there are others with sufficient egos. Because when you correctly said the business case isn't very exciting about this. Diminishing number of payloads, substantial risk. It takes an investor's ego to kind of propel this sort of speculative investment, the glory of spacefaring. So I think as we fear a monopoly we should bear in mind that even in the best case we are going to have an oligopoly, and that is not a whole lot better. We love the retail model where we can get Amazon pricing for everything. It is not likely to be available here, despite Mr. Bezos's involvement. So we don't want to be too idealistic in this pursuit.

And, finally, there is this touchy issue of recruiting brilliant personnel. And we in America relied heavily on Wernher von Braun and lots of other folks who were imported from Germany. And I think the last one just died in the last year or so down in Huntsville, Alabama. So, unquestionably, there are some brilliant scientists who make a difference.

I couldn't help but note on the first page of Mr. Meyerson's testimony, he has recruited lots of folks from lots of places, including someone with Merlin experience. That is interesting. It makes me think, regarding the RD–180, that our failure is not to have recruited a Russian who actually knew how that worked. Where is that person?

And maybe the Chinese did that when they have integrated that into their Long March, or maybe they just stole the blueprints. But you kind of wonder, you hope that a team of scientists can do great things, and, in many cases, they have. But in some cases, at least, there are these brilliant individuals who come up with the secret sauce. And that leads us to the very interesting feature of SpaceX, where they do not rely on the patent system to protect their IP, preferring, instead, the trade secret system, which is basically thumbing their nose at the entire Western system of protecting intellectual property.

And I am not defending the inefficiencies of the Patent Office or—you know. But, this is kind of an interesting challenge here. You just keep it locked up in a safe like maybe the Coca Cola formula as opposed to publishing and disseminating and then protecting legally. So there are many challenges we face as we get into this issue to make sure that we have assured access to space, that we have a perhaps unique national security capability to lift whatever is required on the timetable that we need to serve the warfighter, and, yet, we are increasingly relying on commercial models, global models, international models that may or may not service this unique national capability.

So these are some of the challenges the subcommittee faces as we try to come up with some sort of fair solution that, above all, puts America first. So that is how I see it.

If you all publicly or privately have corrections, amendments to that, modifications, I would appreciate hearing from you, because we are trying to do the right thing and not have Congress mess up yet again like we did last year.

Thank you, Mr. Chairman.

Mr. ROGERS. I thank the gentleman.

I would note, when Congress messed up last year, it was with language the private sector gave us to put in that bill. We didn't dream up that language.

Let's go to the gentleman from Oklahoma, Mr. Bridenstine, for any additional questions he may have.

Mr. BRIDENSTINE. Thank you, Mr. Chairman.

Mr. Bruno, you mentioned earlier to close the business case, ULA will need to be able to compete in the commercial sector for space launch; is that correct?

Mr. BRUNO. Yes.

Mr. BRIDENSTINE. Mr. Meyerson, does Blue Origin intend to also compete in the commercial space launch industry with its own system?

Mr. MEYERSON. In the very long term, yes, we do. Our first iteration we are working on is our suborbital New Shepard vehicle, which we flew last month, and our focus on our rocket engines as a merchant supplier to ULA and other companies and making those engines available.

Mr. BRIDENSTINE. So if—and just for you, Mr. Bruno, if Blue Origin enters a space, and they are competing directly against you in the commercial market, and you are entirely dependent on them for your rocket engine, does that pose a risk to the costs of government launches?

Mr. BRUNO. In the foreseeable future, I see our activities in the marketplace as complementary. And what my colleague Rob is referring to is in the far future, when we will have ample opportunity to work out arrangements.

Mr. BRIDENSTINE. If the AR1 engine ultimately is not what is down-selected, what is the future for the AR1?

Ms. Van Kleeck.

Ms. VAN KLEECK. Currently, the AR1 is relevant to this particular change in launch vehicles in this particular point in time. We don't re-engine launch vehicles. You know, but every 10 years we have different opportunities to do that. We would maintain the technology. We would probably put it at a technology level. But if there isn't a launch vehicle provider that will use it, the development will not be completed at this point in time.

Mr. BRIDENSTINE. Is there a chance that that launch vehicle provider might materialize and the AR1 would find itself relevant in both commercial and the EELV program?

Ms. VAN KLEECK. It is possible. There are—it clearly depends on what some of the launch vehicle providers, what their paths going forward are. But, as you know, there are multiple providers here on this panel, and we have talked about a limited market. So in the near term, it is not a high probability.

Mr. BRIDENSTINE. One of the—one of the challenges we have is—certainly, it seems like there are two different directions that the panel is trying to accommodate. One direction is the Air Force's position, which is we need to purchase launch as a service. And, of course, that has been the going mindset for everyone for quite a while. Then we ended up in this position where the Russians got aggressive. And, boy, I will tell you, I share Chairman Rogers' position. We don't want to send one more dollar to Russia that we don't absolutely have to send to them. And certainly I agree with Chairman Rogers that we need to do everything possible to mitigate the risk to our own assured access to space. That is kind of what drove us to this position today where we have got language in the NDAA that ultimately might not be compatible with language that says, we need to purchase launch as a service.

So this is a challenge we are going to continue to have. Unfortunately, the panelists today find themselves in a challenge where they are trying to basically go two different directions at the same time, given what has happened in the world. And, of course, we as Congress, need to figure out a way to make this the best for our country, the best for the taxpayers, the best in the national security interest of the United States. I know Chairman Rogers has that in his heart. The goal here is to get off any Russian engines and to make sure we have assured access to space. And we have got to make that happen. And I just appreciate you guys being here and working through this with us as we try to make it happen for our country.

Thank you guys very much.

Mr. ROGERS. I thank the gentleman. And I concur with that completely.

The Chair now recognizes the gentleman from Colorado, Mr. Coffman, for any additional questions he may have.

Mr. COFFMAN. Mr. Chairman, I have one question.

Mr. Meyerson from Blue Origin and Mr. Thornburg from SpaceX, has a large methane rocket engine ever been built and flown in space? And why is this? And what are the advantages and the challenges of building this type of engine?

Mr. MEYERSON. By and large, I will say no. Engines that are greater than 250,000 pounds in thrust, there has been no large methane engine that has been built and flown to space that I know of. We have been busily working on the BE–4, and we have made some specific design choices to mitigate any risk with that development, design choices in our chamber pressure, design choices in our injector, and design choices in our materials that will give us confidence that we can develop this engine by the end of next year, get into testing, and meet the Vulcan launch vehicle requirements.

Mr. COFFMAN. Mr. Thornburg.

Mr. THORNBURG. To your first question about have we flown a large methane rocket engine, no, we have not done that. But the one thing I did want to point out is that the one aspect of, as you hear a lot about this novel technology in some of the new engine power plants that are being discussed today, I wanted to point out to the committee that the one common thread across, whether it is Raptor, whether it is AR1, or whether it is BE–4, is really the ox-rich staged-combustion technology. All three engines that the three companies are working on incorporate that. And that really does represent the technology coming to the table.

So whether you are trying to replace something with Atlas in terms of an AR1, you still have to finish the development of ox-rich staged-combustion technology. And it is the same for BE–4; it would be the same for a Raptor engine.

And I wanted to also comment that the talented engineers in the United States have been working on these types of technologies since the late 1990s. Through programmatic investments of the Air Force Research Laboratory and NASA, these technologies have been available, but have yet to be fully funded and brought to the table until these conversations are happening now. So that is kind of where we stand on the methane engine development.

Mr. COFFMAN. Would anyone else like to comment on that?

Ms. VAN KLEECK. Yes, sir, I would. I agree that the common thread through these things is the ox-rich staged technology. However, I would say there has been—I mean, we have worked on methane as a company, Aerojet Rocketdyne has worked on methane since the 1960s, and we have built a number of different devices, none of which have flown yet. Methane is probably going to be an important technology for Mars missions when you are dealing with landers and things like that where you want to make your propellant in space.

In terms of the difference, though, between a methane and a kerosene engine for a booster, the ox-rich side is the same, but the fuels, kerosene is characterized. The ability to run kerosene in an ox-rich environment is also characterized. The Russians have perfected this technology over decades.

I am confident we can also do that with methane, but it is going to take time. It took the Russians a long time to get where they are. I think we understand what they have done. We will be building off of that technology. We have studied that technology for 20 years. I believe this can also be done for methane, but I think the timeframe is going to be quite a bit longer.

Mr. COFFMAN. Anyone else comment? Yes.

Mr. CULBERTSON. Not about methane, sir, but I would like to point out that there are other technologies involved here that involve propulsion systems, and they have been mentioned several times, and that is the solid rocket motors that contribute to our access to space, whether they are strap-ons or main stages.

That is a part of our heritage as a country and Orbital ATK is very much involved with that and working with several people here on the panel on making sure that that is a part of their systems. Any system going forward is going to have to have either newly developed or perfected solid rocket motors as a part of it, whether it is the main engine or additional propulsion or second stages. And I think that that needs to be a part of the discussion too, is how to maintain the lead that we have in this country in solid rocket motors and solid rocket propellants over the rest of the world to help with national defense, as well as our access to space for these big payloads.

Mr. COFFMAN. Yes, Mr. Thornburg.

Mr. THORNBURG. Just a comment back on the methane side. I think the research and development and the testing that has been performed by SpaceX's private investment, as well as activities we have been having with Blue Origin, are proving out the viability of methane as a fuel, whether it is ox-rich or a full-flow staged-combustion cycle.

I would also like to say that we have been operating hydrogen propulsion systems in this country since the dawn of the space age. Hydrogen, obviously, offers a lot more complexities in the design, et cetera. Methane typically falls somewhere between hydrogen and kerosene in terms of handling due to the nature of its cryogenic properties.

But I did want to point out that there has been a lot of research and development in methane ongoing in the private sector, independent of government investment over the last several years.

Mr. MEYERSON. Can I just add one comment to that? We talked about methane, but the choice of fuel for the BE–4 is liquefied natural gas, which is commercially available methane. It is the commodity that you can buy, and the infrastructure in the U.S. is growing rapidly in the last decade. So we have chosen LNG because it is cheap. It is four times cheaper than kerosene, RP–1, the rocket propellant grade. It is available, and it is clean. So it supports reusability applications, which we are interested in, in the long term. And those are very important points that I want to add.

Mr. COFFMAN. Thank you, Mr. Chairman, I yield back.

Mr. ROGERS. I thank the gentleman.

The Chair now recognizes the gentleman from Colorado, Mr. Lamborn, for 5 minutes.

Mr. LAMBORN. Thank you, Mr. Chairman.

Mr. Thornburg, I would like to drill down just a little bit more on a line of questions I was pursuing earlier to hopefully get a little more clarity. In response to a question for the record from the last hearing, General Hyten stated that, quote, "SpaceX has not formally submitted the changes desired to be accepted under certification for the full thrust system to the Air Force," unquote.

If SpaceX hasn't formally submitted the changes, then how is it that your system should be certified for launch or eligible for competition on EELV?

Mr. THORNBURG. Sir, I would have to get back to you on the specifics of what has been transferred. But I can tell you that to my knowledge presently, since the last hearing, there have been numerous conversations between the Air Force and SpaceX specifically to address this information. I believe the bulk of all that has been provided and is being discussed between the Air Force and SpaceX. But I am happy to take that and provide it back for the record.

[The information referred to can be found in the Appendix on page 167.]

Mr. LAMBORN. Well, that doesn't really satisfy me. Let me approach this from a little different angle. And I am going to refer to an article from March 17 of this year, Aviation Week article entitled "SpaceX Sees U.S. Air Force Certification of Falcon 9 By Midsummer." Okay. And here is a quote out of that article. And it is a lengthy quote, so bear with me a minute.

"This year, SpaceX expects to debut another Falcon 9 upgrade, one that will see at least a 15 percent increase in thrust for the

Falcon 9's Merlin 1D core-stage engines and a 10 percent increase in the upper stage tank volume. NASA has said such an increase in thrust is likely to require significant design modifications to the engine and rocket, which could necessitate additional certification work, including a series of successful flights to prove the vehicle."

So how is it that NASA can say that these are significant modifications and that they require additional certification and possibly test flights, and yet you don't seem to think that there is a need for more certification?

Mr. THORNBURG. The language you use, no need for more certification, just to clarify, I guess my comments earlier were mainly with regards to resetting the clock on certification. There has been ongoing certification work to upgrades of launch vehicles long before SpaceX was in existence. So my comments there were mainly focused on the fact that SpaceX is not doing anything different than ULA has done over the years with Atlas and Delta in terms of bringing on new improvements to systems that improve performance and costs.

I can also say that we are working very closely with NASA and the Air Force, who have both certified us for their launches, for their own payloads this year, and we have ongoing conversations with them with regards to the status of the vehicle. They are fully read into all of the changes, all of the modifications that are planned and are ongoing, and are fully supportive of what we are doing in terms of gaining the certification for upcoming launches.

Mr. LAMBORN. Okay. Well, let me change gears and ask my last question. You stated in your opening statement that there should be a 50–50 investment in a new engine. Did SpaceX follow that guideline for Falcon 9 investment?

Mr. THORNBURG. With Falcon 9 investment, SpaceX 100 percent invested in development of that launch of that vehicle. So, yes.

Mr. LAMBORN. You said 100 percent. It is my understanding that the bulk of SpaceX's capital is actually forward-funded NASA contracts totaling around $3.5 billion. Is that correct?

Mr. THORNBURG. I can't speak to the total. But if you are referring to the COTS [Commercial Orbital Transportation Services] program itself, the NASA money under the COTS program to supply the space station was focused on the Dragon space capsule versus the Falcon 9 launch vehicle, which SpaceX funded the development of.

Mr. LAMBORN. Okay. Thank you.

Mr. Chairman, I yield back.

Mr. ROGERS. Thank you.

Really, I appreciate all of you all.

Mr. Thornburg, you made a great point when you emphasized we got ourselves into this situation, and the ranking member did, when the U.S. stopped investing heavily enough in this technology and developing where we need to be and where we should have been before now. But our full attention is focused on the matter now, and we appreciate you being here.

I would remind all the witnesses, we are going to keep the record open for at least 10 days in case any members have any additional questions they would like to ask you to respond to for the record, and I would appreciate a timely response to those.

We are about to have another panel of government witnesses. I very much hope you will listen to them and let us know what you think about what they say, because it will continue to help us as we continue to grow and develop in trying to move this policy in the right direction.

And with that, we stand in recess for this panel to adjourn and then bring the new panel in.

[Recess.]

Mr. ROGERS. I would now like to welcome the experts for our second panel. I want to thank you all for coming here today and preparing for it. We have the Honorable Katrina McFarland, Assistant Secretary of Defense for Acquisition; General John Hyten, Commander, Air Force Space Command.

And, General Hyten and Ms. McFarland, it is great to have you back to testify on this topic. We truly appreciate your opinions.

And we also look forward to hearing from Lieutenant General Sam Greaves, Commander, Air Force Space and Missile Command Center. And we also have Dr. Mike Griffin, who is representing himself today, but he was deputy chair of the SecDef's [Secretary of Defense's] RD–180 Availability Risk Mitigation Study, and he is also a former NASA Administrator.

Ms. McFarland, I will turn it over to you to start with. You are recognized for 5 minutes to summarize your opening statement.

I will tell all the witnesses, your opening statements in full will be submitted for the record. If you would just like to summarize with your time, we will get right to questions.

Ms. McFarland.

STATEMENT OF HON. KATRINA G. McFARLAND, ASSISTANT SECRETARY OF DEFENSE FOR ACQUISITION, DEPARTMENT OF DEFENSE

Secretary MCFARLAND. Thank you, Chairman Rogers, Ranking Member Cooper, and distinguished members of the committee. I appreciate the opportunity to speak and appear before this committee, particularly since you are supposed to be at recess. And I ask that my written testimony, as you state, be taken for the record.

Mr. ROGERS. Without objection, so ordered.

Secretary MCFARLAND. Thank you.

Assured access to space continues to be critical to our defense space capabilities and national security, especially as our world has changed over the last decade into a nonpermissive environment.

During our March 17 hearing on assured access to space we touched on many topics concerning the Evolved Expendable Launch Vehicle program. Amongst those were the Department's plans for reintroducing competition on how we procure our launch services for national security space, or NSS, satellites and our plan for transitioning away from the use of the RD–180 engine, the Russian engine, onto domestically sourced propulsions capabilities.

And while I am pleased to state that we are making progress on both of these, competition and transition is intrinsically and fundamentally intertwined. This interdependency can't be ignored. It must be managed. And as you heard with the members from before us, it is a complex issue. And with SpaceX Falcon 9v1.1 launch system now certified for NSS launches, we have for the first time since ULA's joint venture formation enabled competition for NSS launch contract services.

However, section 1608 of the fiscal year 2015 NDAA prohibits any use beyond the Block 1 contract with ULA for our most cost-effective launch capability, ULA Atlas V, which relies on that Russian RD–180 engine. As enacted, section 1608 creates a multiyear gap without at least two price-competitive launch providers and trades ULA for SpaceX as the sole providers on medium and some intermediate NSS launches. It also impacts ULA's viability to compete in the future, as discussed, as an estimate to replace and certify this capability is optimistically about 7 years. And, yes, I am a recovering engineer, and it is a complex issue, sir.

To avoid this unacceptable situation, the Department submitted Legislative Proposal Number 192 requesting section 1608 be amended. The Department believes this legislative proposal, combined with the addition of the newly certified SpaceX Falcon 9v1.1, enables the Department to minimize impacts to its assured access to space-based capabilities while industry completes its transition using domestically designed and produced propulsion systems. The Department greatly appreciates this subcommittee's support of the legislative proposal and looks forward to working with Congress and the defense committees as the fiscal year 2016 budget authorizations and appropriation languages are debated.

The Air Force released a request for information, RFI, you have heard some of it earlier, to industry around August 2014 soliciting feedback on approaches for transitioning away from the RD–180. Responses supported the Department's strategy to co-invest with industry to transition off the RD–180 and provide launch capabilities able to support NSS requirements, but markedly broader approaches than anticipated, as you heard.

As a result of the RFI and in order to comply with the commercial space trade transportation services and assured access to space mandates, the Air Force developed a four-step incremental strategy to fully transition onto domestic propulsion capabilities as being discussed. The Department remains committed to working with Congress and industry to transition off this RD–180 engine in the most efficient, expeditious, and affordable manner possible while ensuring continued compliance with the assured access to space and commercial trade space transportation service laws.

Again, thank you for your support to our critical missions, and I look forward to our discussion.

[The prepared statement of Secretary McFarland can be found in the Appendix on page 128.]

Mr. ROGERS. Thank you, Ms. McFarland.

General Hyten, you are recognized for 5 minutes.

STATEMENT OF GEN JOHN E. HYTEN, USAF, COMMANDER, AIR FORCE SPACE COMMAND

General HYTEN. Thank you, Mr. Chairman, Ranking Member Cooper, distinguished members of the subcommittee. It is an honor to appear before you again to talk about this important issue with my distinguished colleagues. Thank you all for your continued efforts to work this hard topic, because, as Ms. McFarland said, it is a very difficult topic to try to work through.

So I believe everybody has been fortunate enough to witness our Nation's evolution in space power, while our combatant theater commanders have fully realized how fundamental space-based effects are to every military operation that takes place on the globe today. However, these capabilities are merely an illusion without assured access to space. With today's national reliance on space capabilities, assured access has gone from important to imperative and remains one of our highest priorities.

The launch industry has fundamentally changed over the last few decades. The Air Force no longer owns the vehicles we launch. We purchase access to space as a service. And industry is now investing large amounts of private capital in developing new engines and rockets, and we are collaborating closely with them to determine how best to invest in public-private partnerships and U.S.-made rocket propulsion system.

So within context of assured access to space, it is absolutely critical that we move as fast as we can to eliminate reliance on the Russian RD–180 rocket engine. The United States should not remain dependent on another nation to assure access to space, and we need an American hydrocarbon engine. That will be a significant challenge, but we think, with the efforts and ingenuity of our government and industry teams, it is possible to develop an American engine by 2019.

However, the engine still has to be made into a rocket. It still has to be made into a complete space launch system. And even if that system looks similar to the Atlas V, we still need to integrate that new engine, test it, certify it, and that is going to take another year or two once the engine is developed. We do not want to be in a position where significant resources have been expended on a rocket engine and no commercial provider has built or modified the necessary rocket.

This subcommittee can be assured of our commitment toward competition and a healthy space launch industrial base as we move as fast as we can towards U.S.-built rocket engines. Thank you for your support. I look forward to continuing in partnership, and I look forward to your questions.

[The prepared statement of General Hyten can be found in the Appendix on page 135.]

Mr. ROGERS. Thank you, General Hyten.

General Greaves, you are recognized for 5 minutes.

STATEMENT OF LT GEN SAMUEL A. GREAVES, USAF, COMMANDER, AIR FORCE SPACE AND MISSILE SYSTEMS CENTER

General GREAVES. Chairman Rogers, Ranking Member Cooper, and distinguished members of the subcommittee, thank you for the opportunity to appear before you today.

Space capabilities are essential to the American way of life, and they multiply the effectiveness of our warfighters. Thanks to the efforts of the men and women of the Space and Missile Systems Center, our many contractors, and many mission partners, we continue to deliver worldwide precision navigation, threat warning, protected strategic and tactical communications, and many other capabilities from space.

As we have all come to know, space launch is a key to providing all of that capability. We address the critical nature of space launch through a policy of assured access to space. Maintaining at least two reliable launch systems is a credible method for continued access to space should one suffer a grounding event. As part of this approach, we purchase launch services on a commercial basis, leveraging America's most important source of innovation and national economic strength, our free market.

These two concepts, assured access to space and competition, are the cornerstones of our national launch policy. They guide our implementation as we execute the 2015 National Defense Authorization Act, which outlines the use of the RD–180 and mandates that we develop a next-generation rocket propulsion system.

In response, I will emphasize that the Air Force is 100 percent committed to transitioning off of the RD–180 for national security space launch as quickly and as prudently as possible to a domestically produced liquid- or solids-based rocket propulsion system.

From our perspective, solely replacing the RD–180 with a new engine is not the complete solution, since rockets are heavily influenced by engine design. Even a drop-in replacement which closely matches the RD–180 physical interfaces and performance would require modifications to launch vehicle structures, the fuel and oxydizer feedlines, and the heat shields to accommodate even minor differences in performance.

As was mentioned by the previous panel, the thrust vector control and throttling of the RD–180 engine is a critical characteristic of the Atlas V. The new engine's thrust vectoring and throttling will require changes to the electronic control systems and significant engineering analysis to develop new flight profiles to launch the various satellites.

So, in other words, a rocket engine specifically engineered to replace the RD–180 on the Atlas would most likely be usable only for ULA's Atlas and not by any other launch service provider without significant modifications to the engine and/or the launch vehicle. We also do not believe this would meet the intent of open competition.

Additionally, as a product of our market research, we found that if we procured an engine not designed for a specific launch vehicle, commercial providers would be unlikely to build a rocket around it without the government also funding the redesign of their launch vehicles, adding time, cost, and risk we cannot afford.

So the Air Force is pursuing a strategy of shared investment with industry using public-private partnerships at the launch service level. The goal of this plan is to produce at least two domestic, commercially viable launch systems, including the accompanying liquid-fuel engines or solid rocket motors.

In our research, we assess that industry timelines predicting complete rocket propulsion systems by 2019 are aggressive. History has consistently shown that developing, testing, and maturing an engine takes 6 to 7 years, with another year or two beyond that to be able to integrate into the launch vehicle.

Now, with all that said, we are moving fast, very fast on this. To execute this plan, we have developed an aggressive four-step acquisition strategy to reach this end state as quickly as possible. Step one pursues technical maturation and risk-reduction efforts, building our expertise within the U.S. Step two targets shared investments in rocket propulsion system development. Step three guides the transition of our shared investments into the provider's launch system. And finally, step four directs the acquisition of launch services to meet national security space requirements.

As we move forward, our overall goal is to preserve assured access to space by maintaining our laser focus on mission success. Our approach will accomplish this by supporting competition where it credibly exists and by acquiring space launch as a service from certified, commercially viable providers using domestically produced rocket propulsion systems. If we do this, we will be on a path to transitioning off of the RD–180 and having at least two domestically produced, commercially viable launch providers that are certified to meet national security space requirements by the end of fiscal year 2022.

Thank you for your support in helping us get here, and I look forward to your questions.

[The prepared statement of General Greaves can be found in the Appendix on page 143.]

Mr. ROGERS. Thank you, General Greaves.

Dr. Griffin, you are recognized for 5 minutes.

STATEMENT OF DR. MICHAEL D. GRIFFIN, DEPUTY CHAIR, RD–180 AVAILABILITY RISK MITIGATION STUDY

Dr. GRIFFIN. Thank you, Mr. Chairman.

Chairman Rogers, Ranking Member Cooper, and distinguished members of the committee, I am honored to be asked to appear before your subcommittee to testify on the matter before us today. However, before beginning any substantive discussion, I think I should note for the record that I am here as an independent witness and a private individual. I have received no consideration of any kind in connection with the topic of today's hearing from anyone. I am here on personal leave and at personal expense and do not represent any company, agency, or committee on which I have served in the past or presently serve.

So with that said, we are here to discuss the RD–180 and its replacement. The RD–180 has been used for two decades on various versions of Atlas. And without that engine or a functionally equivalent replacement, today's Atlas V launch vehicle will be grounded and with it two-thirds of our national security payloads as we presently have the manifest.

And so while I completely agree that we should not continue to be dependent upon a foreign power, much less an adversary, for any element of our national space launch capability, I do believe that the legislative action which has been taken in this regard is a bit too abrupt. It might be that we should wean ourselves of this dependence a bit more gently.

But if the Atlas is grounded, then what? Well, U.S. policy and law require two independent systems for national security space launch capability. This requirement is met, but only partially so, with the Delta 4 family. The previous panel said that payloads could be shifted from Atlas to Delta 4. That is so, but many critical payloads are not immediately interchangeable between these vehicles and would require considerable rework at considerable cost to shift from Atlas to Delta.

Moreover, the Delta is, in general, more expensive than the equivalent Atlas, and the top-end Delta performance of Delta 4 Medium is less than that of the top-end Atlas. So some Atlas payloads will not be transferable to Delta.

Finally, the Delta production limitations are such that without a massive increase in manufacturing and launch infrastructure, very limited surge capacity is even possible.

So the net effect of shifting national security space systems from Atlas to Delta, should we have to do so, will be several years of delay for the average payload and many billions of dollars of increased cost.

Now, some have said that the best forward path is to discard decades of government investment in and experience with the Atlas and develop a whole new system. This does nothing to solve today's problems. And even if it did, it is irrational to suppose that an entirely new launch vehicle can be obtained more quickly or at less cost than a new engine alone.

Others would have us believe that the U.S. Government can merely purchase launch services from among multiple competitors as if one were selecting a particular airline for a desired trip based on airfare and schedule. Purveyors of this launch-as-a-service view would have us believe that if we have an engine supply problem, the U.S. Government should stay on the sidelines while the market solves the problem.

But in reality, the U.S. national security launch architecture is a strategic capability having far more in common with other strategic assets such as fighters, bombers, aircraft carriers, and submarines than it does with airlines and cruise ships. The vagaries of the market cannot be allowed to determine whether or not critical payloads make it to space.

Accordingly, the U.S. Government must be prepared to ensure that the supply chain required to maintain this critical asset remains intact. That supply chain is currently quite fragile, because while we have been supporting the Russian rocket engine industrial base, our own has withered.

To conclude, we have an engine problem, not a rocket problem. I believe we should solve it by building a government-funded, government-owned, American equivalent to the RD–180 as quickly as we can possible do so. We should not allow the many obfuscating issues which have been raised in connection with this problem to cloud our view of what must be done.

Thank you. My full statement, I hope, will be entered for the record.

[The prepared statement of Dr. Griffin can be found in the Appendix on page 154.]

Mr. ROGERS. It certainly will.

Well, listen, before I get into my questions that I prepared, you heard the previous panel. Is anybody just chomping at the bit to take on something that came out in that previous panel that you think the committee needs to hear for sure?

Dr. Griffin.

Dr. GRIFFIN. Sir, I need to comment on one of the last statements of the SpaceX representative, that the development of Falcon 9 was done on private funds and that NASA money spent went on Dragon.

I personally am the originator of the COTS program, and that program was intended to provide seed money—and I emphasize seed money, not majority funding—for the development of a new launch vehicle and a delivery system for cargo to space station.

After I left the agency with the inauguration of President Obama, considerably more money was supplied to SpaceX. I think from public sources it is easily possible to show that SpaceX has received about $3.5 billion or so, possibly more, in open source funding. Seeing as how they have conducted seven launches for NASA, counting the one upcoming this week, that is either an extraordinarily high price per launch of about a half a billion dollars per launch, which I don't believe is the case, or a considerable amount of that money has gone into capitalizing the company.

The money was not segregated out, according to Dragon or Falcon 9, so I very strongly believe that the government money which has been provided to SpaceX has in fact gone for the development of Falcon 9.

Mr. ROGERS. Okay.

Anybody else? Anything that just jumps out at you?

You know, you all heard me hope optimistically that more than two companies are going to be competing for this engine, and I hope that we wind up with three or four or more getting into this competition when it really gets going.

All right. In last year's 2014 space hearing, I asked the witnesses if they think developing a competitively acquired next-generation engine available to all U.S. providers that could effectively replace the RD–180 was important. General Shelton, the predecessor of General Hyten, stated, quote, "I would be a strong supporter of that if we can find the money to do it," close quote. Mr. Gil Clinger, who used to work for Ms. McFarland, stated, quote, "I think in the long run it is in the interest of the United States Government to develop a next-generation rocket, U.S.-produced rocket engine," close quote.

We took their advice and directed the Department to build a domestic propulsion system that ends our reliance on the engines by 2019, and we provided $220 million just to get started.

But, now, when I read your plan, it is not clear to me that we are focused on developing a domestic engine. What has changed since that testimony?

And I would like to ask all the witnesses: In your professional judgment, if we have two options—one, to replace an engine with a proven technology or, two, to build a new engine with an unproven technology, new launch vehicle, and new infrastructure—what is the low risk, most expedient, and the least cost to the taxpayers?

Anybody that wants to take it on.

General Hyten.

General HYTEN. So, Mr. Chairman, I will make two comments, and then I will turn it over to my fellow members on the panel.

So the first comment is that the United States leads the world in two elements of the rocket engine business. We lead the world in solids, and we lead the world in liquid oxygen/hydrogen engines. I think we should lead the world in every category of engine development. The one we don't lead in is hydrocarbon development.

I believe the United States, no matter what the rest of this discussion goes on, the United States should develop a technology program that builds hydrocarbon technology for the United States across the board. I think it is essential to what we do as a country. We have avoided that for about 20 years, and we ought to take that on and go forward to that, however this turns out.

The second issue is what has changed. What has changed since the last time we talked is we actually have a bill, we have a National Defense Authorization Act, that gave us very specific guidance. And the guidance said that we need to pursue engines that grow to a domestic alternative for national security space launches. It tells us they have to be made in the United States; I think all the previous panel did that. They said they have to meet the requirements of the national security space community; I think they did that. Developed not later than 2019; that is a challenge, but we heard that. And then be developed using full and open competition.

That full and open competition is exactly the structure we put in place. We were specifically told by the law not to go to a specific vendor, not to go build a specific engine, but to go look at full and open competition across the industry. And when you look at the previous panel, the thing that struck me about the previous panel that was very impressive is how much they had embraced that across the board, from Blue Origin to ULA to Aerojet Rocketdyne to Orbital ATK to SpaceX, to embrace that, to look at that place.

So the competition was very important, but when you do full and open competition, you have to go through the process to make sure it is full and open and fair across industry. That does not happen overnight.

So I would just make those two comments for the record, sir.

Mr. ROGERS. General Greaves.

General GREAVES. Mr. Chairman, you asked whether or not we should replace the RD–180 with technology. As the previous panel did express, we do not have the capability within the United States today to replace that engine. So whatever we come up with will be a new engine. And the AR1, BE–4, they were both mentioned.

Now, from our point of view, replacing an engine has effects on the overall capability that we plan to deliver. So we must verify the impacts of any changes to any component in the system, especially engine, on the rocket itself and our ability to deliver that capability to orbit.

So, combined with what General Hyten just mentioned, our approach is to look at the total capability, the total system, that will result from any changes to any component, to include the engine. And that is why we start from the launch service ultimate capability, assess what the impacts are, and then decide whether or not, as you will see through the four-step process that we have in place, whether or not any of the providers—and, by the way, we did have what we are referencing as a broad response from industry to the RPS proposal that we put out there that arrived a couple days ago that we are assessing right now. So there is interest. But we must look at the impacts from any changes to the rocket, to the system, on that system.

Thank you.

Mr. ROGERS. Ms. McFarland.

Secretary MCFARLAND. Chairman, I think it was very clear that one thing came out from each of the previous industry comments: There isn't a drop-in replacement for an RD–180 on the table. Form, fit, and function, maybe, but not a drop-in exact replacement.

So really what we are focused on is risks. How do we leverage our funds and risks? Is it going to be leveraging funds from the government and the risk is to the government and we pass that risk back to industry? Or do we take and work together with industry and funding and share the risks? I call it the "pay me now or pay me later."

Each of these industries have already stated there is a limited industrial base for commercialization immediately. I shared with you earlier the Satellite Industry Association study that says there is a modest growth, somewhere between 4 and 9 percent. They, in commercial world, don't use the size as you are familiar with that we have for payloads.

So we carry, no matter what, an underwriting of whatever comes out of here. And because we don't have the IP to the RD–180 and we haven't developed, as has been stated repeatedly here, the engineering expertise that understands the metallurgy and necessarily the methodology to do the propulsions in exact form, we have to assess that we are going to have some modicum of risk.

The Air Force proposal, as it stands, and with their RFP, are pursuing getting the government and industry smart together to the point where they can make a logical decision to the next step. Can we purvey going forward with a launch system? Shall we look at just propulsion system? Shall we look at just engine? And what is the most cost-effective and, by the way, timely—we are racing against time—proposal?

The advancements from industry is reassuring. The question is now where do we place that risk and how can we afford it. Particularly, as I mentioned to you also earlier and with the ranking member, we are concerned with sequestration right in the midst of trying to rush to moving forward on this replacement. It hits us right at our weakest joint, fiscal year 2016.

Mr. ROGERS. You heard the witnesses in the previous panel talk about the degree of modifications that would be required to take one of the new proposed rocket engines and put it on the rocket itself. And they didn't disagree with the numbers I have heard from you earlier, General Hyten, of $200 million for not just the rocket but all the infrastructure changes, and that was the floor.

Do you still believe that is at a minimum what we are going to be looking at, no matter which alternative we select?

General HYTEN. Mr. Chairman, I won't disagree with what Mr. Bruno said—what his numbers are. The numbers I shared with you are the numbers I heard from Mr. Bruno.

We will know more as we actually get into the contract activities with them. General Greaves will be going down that path with him directly. But I think those are ballpark numbers that are fair to look at. But they are not tens of millions of dollars. I think $200 million is the floor.

Mr. ROGERS. Is the floor.

One big change from the last assured access hearing to this hearing that has been striking to me is the idea of hitting 2019 for completion of testing and providing your system for Air Force certification seemed ambitious but realistic. Now, you have heard from the previous panel, with high degrees of confidence, they believe they are going to have not only completed testing of their systems but have completed certification easily by 2019.

General Greaves, you seem to have some real concerns about that. Do you think that is just optimism or silly?

General GREAVES. Sir, I believe they are discussing certification of the engine. When we talk certification, we are talking certification of the system. So the engine, plus everything—any modification to the engine brings with it software, structures, loads, flight dynamics, processing, manufacturing. And that is what we refer to as certification.

So I do believe it is aggressive, but, then, that is only part of the answer.

Mr. ROGERS. So you just created a new question for the record for all of our industry panelists, is we are going to find out if they were talking about—what certification process.

General HYTEN. So, Mr. Chairman?

Mr. ROGERS. Yes, General Hyten.

General HYTEN. I was listening real close, and the BE–4 answer from Blue Origin, the quote was "ready to integrate and fly in 2019," and the Aerojet Rocketdyne was "certification of the engine in 2019."

So I think that is a great question for the record, but I was listening very close to that, as well, to hear what they said about certification.

Mr. ROGERS. Yeah.

Dr. GRIFFIN. May I add a comment, Mr. Chairman?

Mr. ROGERS. Dr. Griffin, yes, I would love to hear your thoughts on this.

Dr. GRIFFIN. I first want to say that I very strongly agree with General Hyten that large hydrocarbon engine technology is one which we let go at our peril, our national peril. I would point out we have never actually agreed not to have it. We just did a make-or-buy decision back in 1995, and we decided to buy it. That option doesn't look so smart right now, and so I think we need to relearn how to make it. I am not interested in replicating RD–180 technology; I am interested in going beyond it. And that is what I believe we will and should do.

Secondly, I believe that there is considerable self-interest on the part of a number of different parties in estimating the difficulty of integrating a new engine on a launch vehicle. I don't think it is a $10 million problem, but I am not sure that I agree that it is a multi-hundred-million-dollar problem.

I actually compiled an incomplete list of 14 different engines which have been used on a plethora of different launch vehicles and stages and 8 different rocket engine stages which have been re-engined over the course of, you know, 50-some years of American space history. I would be happy to submit that for the record.

But I simply—the history of this matter does not show it to be so horribly difficult to re-engine a vehicle, as some of our earlier witnesses were saying. I just——

Mr. ROGERS. And if you would submit that for the record, I would appreciate it.

Dr. GRIFFIN. I will submit that for the record. I just simply don't believe it to be so difficult.

[The information referred to can be found in the Appendix on page 167.]

Mr. ROGERS. Before I go to the ranking member, General Hyten, I want to go back to the specific language you wrote down that Blue Origin and Aerojet offered.

When Blue Origin said they would be ready to fly by 2019, how did you interpret that? Did that mean they had completed the certification process?

General HYTEN. For their engine. I interpreted that as the engine would be ready for us to start into a certification flight test program in 2019.

The certification flight test program takes a year or two, usually about 2 years, to go through from a very first flight of an engine. So that was interesting to me because——

Mr. ROGERS. And what does the Aerojet language mean to you?

General HYTEN. What the Aerojet language means to me was a similar thing, except they said by the end of 2019 the engine would be ready. And they didn't say ready to fly on a rocket; they said it would be ready by the end of 2019.

Mr. ROGERS. Which you interpreted as meaning having completed the certification process?

General HYTEN. The engine, not the system.

Mr. ROGERS. So, in either case, you are talking about just the engine, not the system.

General HYTEN. And that is what I heard from both of them. I heard the engine would be ready in 2019 at best.

But I think it is important to point out that both of those technologies have significant challenges that they are going to have to work through. Now, I believe that industry on both sides, especially on the competitive environment, can aggressively pursue those and get through those.

But methane, as I think a number of the members of committee talked about, is a new endeavor when you get above 250,000 pounds of thrust. And this lox-rich [liquid oxygen-rich] staged combustion across the board has not been done yet. So there are still technical risks to pursue in either activity that we need to remember.

Mr. ROGERS. Great. Thank you.

The ranking member is recognized for any questions that he may have.

Mr. COOPER. Thank you, Mr. Chairman.

I am a budget hawk, and I hate to bring up the issue of sequestration, but that probably is, as Ms. McFarland pointed out, the most important issue we face, not only for this issue but for all the military issues. And this committee has ducked it yet again.

So, to put a fine point on it, under this NDAA, we will be borrowing $30 billion, we say from the OCO [overseas contingency operations] account, but it is not budgeted; increase the deficit. We will probably be borrowing it from China. And yet none of us has thought of or proposed, oh, we would buy the Long March missile from China to meet our gap. But we are taking the money from them. But we wouldn't consider buying their missile based on RD–180 technology.

So I hope the members of this committee and of this Congress will solve the sequestration problem, something that repeated Congresses have failed to do, which dramatically injures our national defense capability. So that is the big issue. So, within that giant issue, we are focusing on this.

I need to ask the witnesses and the chairman this question. General Greaves indicated there has been broad interest in the latest RFP. Great. But that is for more than re-engining. So I am interested to find out and get clarity in this hearing whether the chairman would be interested in a new RFP just for a new engine. Are we buying missile systems, or are we buying new engines?

General Greaves.

General GREAVES. Congressman Cooper, the broad response from industry includes initial proposals from both engine providers as well as launch service providers. So we are assessing that combination as we speak. We received it 3 days ago. We are on a timeline to select the best and get detailed proposals from the remainder.

Mr. COOPER. But any new RFP would delay the whole process——

General GREAVES. Yes, sir.

Mr. COOPER [continuing]. Terribly.

General GREAVES. But we believe that——

Mr. COOPER. And you have already expressed, or at least General Hyten has, extreme skepticism about the possibility of getting a certified engine replacement by 2019.

General GREAVES. Yes, sir. We believe a new RFP would delay the process. But we also believe that the current process we have, the RPS we had, encompasses both opportunities for inputs from engine providers and launch service providers themselves. So, within that sum total of inputs we have today, we believe it is highly likely we will find a way through this.

Mr. ROGERS. And I would respond to the ranking member's question with last year's NDAA specific language on this.

"The agreement includes the House provision with an amendment that would direct the Secretary of Defense to develop a rocket propulsion system that is made in the United States, is developed no later than 2019 using full and open competition, meets the requirements of the national security space community, and is available for purchase by all space launch providers of the United States."

We note that this provision is, quote, "not an authorization for funds for development of a new launch vehicle," period.

And I will submit that for the record.

[The information referred to can be found in the Appendix on page 163.]

Mr. COOPER. But this Congress, this committee, can say 2019. That doesn't mean it is going to happen. And we have heard from our Air Force experts extreme skepticism that that could happen.

General HYTEN. Well, you may have heard skepticism, but I hope you also heard optimism. Because when you get into a competitive environment and you actually engage the best scientists and engineers that we have, I think it is possible to get there in 2019.

The skepticism that I think you are referring to is talking about the significant technical challenges in a couple of areas. And then we also have the thrust vector control issue that was talked about by the previous committee, too, that we have to work through. We are not going to go down that technology path. I think in the long term that would be a good technology program for the United States to go down, as well.

Mr. COOPER. Well, we keep on using this word "competition," at least from the previous panel. There are really only two competitors, if you get down to it. You know, there is the ULA group, and then there is SpaceX. And Orbital wants to get in, maybe, sometime. But this isn't retail environment. There are not lots of folks vying for this lumpy business.

Now, there are more folks interested in commercial, but that is not what we are talking about here. You know, this basically, at least due to market interest, is not an interesting business space unless you are a multibillionaire with a big ego.

And, by the way, the missing billionaire for the hydrocarbon engine? Maybe we could find a Texas oilman who would be interested in funding a hydrocarbon research platform. Because Dr. Griffin is probably right; we need world-class research in this area. Well, where has it been for decades? You know, we haven't had the backing for it somehow. So we are in this fix right now.

Dr. GRIFFIN. We were buying it from Russia because it was, in Ms. McFarland's earlier words, pay me now or pay me later. And we chose to take the route of buying a relatively inexpensive recurring engine rather than preserving our own industrial base. At this point, that does not look like it was the smart alternative then, and I would suggest that we do not repeat it.

Mr. COOPER. Well, I don't want to put words in your mouth, Dr. Griffin, but there are some advantages sometimes to big government. And you proposed a government-funded and government-owned solution. Many of my colleagues across the aisle call that big government, and they resist that. They want to turn over virtually everything to the private sector.

Dr. GRIFFIN. Well, sir, I am a free-market conservative. And if I thought that the market were such as to supply this item, as it does for airline transportation or computers, then I would want the government to buy it off the market.

My observation is that—well, I will just put it like this: Last year, ULA conducted one commercial launch and something like a dozen national security or other government launches. That is the ratio here of free market to national requirements.

So I am urging the committee to consider regarding this item as a national security item first, with some possibility of dual use.

But for the national security side, if we believe it to be so, then we must ensure our supply chain. And that is everything from thrust vector control systems and guidance systems to ground infrastructure to airframes to engines. We must ensure that, cradle to grave, we in the national security community have taken care that we can get every item we need.

Mr. COOPER. I like your argument, because we do need assured access to space. I think you went a little bit too far if you used the ULA ratio last year as the appropriate mix. It could be that ULA is the higher-cost provider for commercial, and that is why so much of the business has been taken by SpaceX.

But, regardless of that, there are certain needs that only the government can perform, and we should step up and do that and fully pay for those, unlike we are doing with our overall defense budget. Because we are still relying on sequestration and borrowing the money, essentially from the Chinese. So we have to get real about this, and this committee has failed in that regard.

I am a little worried about the aspect of the Air Force demanding, you know, competition and performance and everything like that, and then you are the gatekeeper. So you could slow-walk or prevent an otherwise-qualified vendor from achieving success. This assumed horizon of 6 to 7 years is worrisome because we won World War II in that timeframe, but now everything is slower in the modern age.

So I am a little bit worried, and we saw this a little bit with the last SpaceX certification. It was 6 months, at least, longer than expected. And I want to make sure all the i's are dotted and t's are crossed, but sometimes we are not quite sure where it is lost in the bureaucracy.

General Greaves.

General GREAVES. Congressman Cooper, just let me restate that we are 100 percent focused on expediting our transition off the RD–180, as well as ensuring that we have a level playing field between all applicants for that work effort. And we have not, to date, excluded any of the proposed options, to include solids.

We have the four-step process, which will drive us to a conclusion expeditiously. And we do have the opportunity, if we find that for one or more reasons that one or more of the proposals that we are reviewing now will not close from a business-case perspective, won't meet requirements, someone can't meet what we need, to essentially go back to step one, which is the technical maturation activity, to pursue an engine development if needed.

Mr. COOPER. See, that sounds like such a great answer. And you said "expeditiously," and that sounds great. But the definition of "expeditiously" in the modern age is 6 to 7 years.

General GREAVES. Sir, I am talking for step two, which is the RFP that we are currently assessing, awards between September and December of this year. It is a two-step process. Does the set of initial proposals that we have now even meet or not meet the requirement? Narrowing it down and moving on.

Because, as you heard from the previous panel, sir, these providers have been working on this issue for quite some time on their own, and we do not believe it will take an exorbitant amount of time to get to a decision.

Mr. COOPER. Well, we all hope it won't be an exorbitant amount of time, but, you know, we heard the FAR 15 problems, and no one has ever proposed to us reforming FAR 15.

Ms. McFarland.

Secretary MCFARLAND. If I could, I think that was one of the things that is underlying your question. What the Air Force used was an other-than transaction. They aren't using FAR 15. That is similar to what you see in DARPA [Defense Advanced Research Projects Agency], I am sure. That is a very important tool that they are using to expedite not only the speed but the innovation. It is not as proscriptive as we discussed in that earlier one.

Mr. COOPER. So it is not as scary as FAR 15, the big monster, but this is a little monster.

Secretary MCFARLAND. This is like boo-boo.

Mr. COOPER. Well, I am sure they will be comforted by that.

Essential question of fact here. SpaceX testifies that they can handle 60 percent of national security loads—60 percent. Okay. Ms. McFarland, in her testimony, said that they can do four of eight, which sounds like 50 percent. And then Dr. Griffin, in his testimony, said two-thirds of the payloads would be grounded. You know, so what is it?

Dr. GRIFFIN. Well, I will answer first.

I was privileged to be asked to serve on the Mitchell Committee last year as deputy chair to look at RD–180 alternatives, and we surveyed the manifest at that time. And two-thirds of the individual flights in the manifest were on Atlas V, one version of it or another. That is just a fact.

When SpaceX talks about "can lift 60 percent of the payloads," I am not arguing that that is not the case, but many of those payloads will be repeat versions of the same thing. It doesn't mean that they can lift 60 percent of all possible spacecraft that the national security community has to be launched.

Mr. COOPER. Uh-huh.

Do we have the legal ability here to force the continuation of the Delta Medium? Because that is what SpaceX claims would eliminate any gap even today.

Dr. GRIFFIN. Sir, I am not a lawyer.

Mr. COOPER. Uh-huh.

General Greaves, you are a lawyer, aren't you?

General GREAVES. Yes, sir.

I believe the entire discussion of the Delta IV revolves around the ability of United Launch Alliance to remain competitive with something like a Falcon 9. And, as Mr. Bruno mentioned before, they are asking for the time to transition between where we are today and whatever their new system, the new—the Vulcan is. And, to do that, they need a steady stream of revenue to maintain the capability to get there.

So, from what they have briefed us, they have briefed me, if the Delta IV was forced to compete with the Falcon 9, it would not be cost-competitive and most likely would not win. So, without that—and Mr. Bruno mentioned it in the previous hearing—without that assurance of that steady stream of revenue, it would be hard to receive the capital investment they need to make that transition.

So it is not, in our opinion, a matter of whether or not the Delta IV can meet our requirements or we can force them to stay. I believe it is a matter of whether or not ULA can remain in business during the transition with the Delta IV as the competitive item.

Mr. COOPER. So we could make it happen if we paid them to make it happen.

General GREAVES. Yes, sir.

Mr. COOPER. Okay.

Final point would be this. I am worried overall that the short tenure of generalships does not meet these multiyear national security capabilities. Because so many of the personnel and leaders of these companies are retired Air Force, and, you know, when we have 3-year, 4-year tours of duties—and I am not impugning anyone's integrity. It just seems like, when we have a 20-year or 30-year time horizon on some of these things and we are rotating in and out personnel, success is sometimes defined as punching your ticket on your command. And, if that is sufficient, you know, that—because we are on the receiving end of a 20-year problem here, and I wonder where those folks are.

General HYTEN. So I understand the argument, Congressman. I really do. And it may be an anomaly, but I will just point out that I came back into this element of the business in February of 2010. And I started coming over here to the Hill in February of 2010, working this issue as the space acquisition person under the acquisition chain for 2 years, then as the vice commander of Space Command, now as the commander of Space Command. So I have been in this area, focused on this area for over 5 years now.

And this is essentially important to me, personally, to make sure we get this done correctly, because I don't want to leave a problem for the people that come after me. Because I understand that I have a finite amount of time left in the service now, and I want to make sure that we get it right so that the folks that come after me don't have to worry about this problem.

Mr. COOPER. Yeah. And you are a good man, and 5 years on a problem is a very long time for the Air Force. But that pales in comparison to Admiral Rickover's tenure with Navy Nuclear.

General HYTEN. It does, sir. I understand the argument.

Mr. COOPER. Yeah.

Thank you, Mr. Chairman.

Mr. ROGERS. And the point the ranking member is making is one I completely agree with. It is one of my frustrations in this world that is so complex that we have these short tenures of really sharp people like you. And it would be awful nice if we could make those, instead of 3-year tenures, 6 years or thereabouts.

Anyway, the gentleman from Oklahoma, Mr. Bridenstine, is recognized.

Mr. BRIDENSTINE. Thank you, Mr. Chairman.

Since the issue of the sequester came up, I will take an opportunity to share what I think a lot of us on this panel worked on very hard. Every year, we reauthorize the Department of Defense. Every year, we appropriate funds for the Department of Defense. We have done that again this year, and we have found a way to unwind the sequester on defense for a year and meet the President's budget request.

Some people would argue that the color of money isn't right. I would argue that they are correct. I would also argue that the money spends the same way, and the money is all green, and what we need to do is unwind this defense sequester permanently. But, for now, we have funded the Department of Defense at the President's budget request level. That is what we have done. And we worked really hard on both sides of the aisle to make this happen.

I would also let people know that, when the President threatens to veto defense appropriations or to veto the NDAA after we met his budget request, the world is listening to that, and it doesn't help the situation at all.

This is an important issue. We need to unwind the defense sequester permanently, and, certainly, I support that. But the reality is, every year, we reauthorize the Department of Defense. Every year, we appropriate funds for the Department of Defense. This meets that same situation.

My question is, when I heard General Greaves talk about technical maturation—that is step one—and risk reduction as part of step one, rocket propulsion system investment as step two, launch systems investment as step three, this sounds an awful lot like the same process that Dr. Griffin went through with COTS.

And my question for you, Dr. Griffin, is, why is it inappropriate now but it was appropriate then? Was the COTS program unsuccessful? Which—now we have commercial crew and commercial resupply; it seems like it is at least working. Why is this different?

Dr. GRIFFIN. Well, a major difference, I think, is in the amount of money involved. In the COTS program at NASA—now, this is taking us back nearly 10 years—we allocated, as we intended, a fairly small amount of money across two providers, and the clear terms of the agreements were that there would be a very significant majority of corporate investment. That was our plan at that time.

The program did work. We got two new launch vehicles out of it, domestic launch vehicles: the Falcon 9 and the Orbital ATK Antares.

I think it is a very different thing for the national security launch infrastructure to be told to purchase launch as a service, implying that there is an open market of providers from which the Department can buy a launch on a marginal cost basis, as if it were an airline ticket——

Mr. BRIDENSTINE. Real quick——

Dr. GRIFFIN [continuing]. And then, oh, by the way, to be told that they have to fund the development of that capability.

Mr. BRIDENSTINE. Is that not what COTS was? COTS was the funding of the development, ultimately, right, that led to——

Dr. GRIFFIN. A small portion of the development.

Mr. BRIDENSTINE. So the level of the investment was——

Dr. GRIFFIN. Money matters. That is exactly right. The level of the investment matters a lot. When we established the COTS program, we wanted to see a major element of contractor skin in the game. We did not want the skin in the game to be entirely that of the government. If the government was going to fund it as a new development, then we should just do it as a prime contract.

Mr. BRIDENSTINE. Okay.

I just have a few seconds left. And I just want to reiterate the point I made earlier, which is the Department of Defense will be fully funded, and the President needs to sign that into law.

And I think it is critically important that we not, you know, take risk of, you know, shutting down the Department of Defense because the President believes we don't have enough money spent on the IRS [Internal Revenue Service] or enough money spent on the EPA [Environmental Protection Agency] or the National Endowment for the Arts. That is not an appropriate thing to do, especially given the threats that we face in the world.

With that, Mr. Chairman, I will yield back.

Mr. ROGERS. I thank the gentleman.

The Chair now recognizes Mr. Coffman from Colorado.

Mr. COFFMAN. Thank you, Mr. Chairman.

And, General Hyten, everyone appears to be in unanimous agreement on two points: first, that competition is good since it provides cost savings and resiliency; and, two, that we need to eventually transition off the Russian RD–180 engine.

I am very concerned we haven't rationally thought through that process and the timelines. In other areas of national defense, we would never consider phasing out a capability until we had confidence in a follow-on—for example, F–35 will be ready to fight before phasing out the F–16. You know, as a combat veteran, I would never advocate for the phase-out of one weapon system until I was confident the follow-on system is operationally ready to support the mission. In this space launch arena, we are anxious to phase out the RD–180 engine without full confidence that a robust capability is ready to replace it.

What is the Department doing to ensure there is no gap in assured access to space between the time the Atlas and Deltas are phased out and the follow-on Vulcan and Falcon Heavy become operational?

General HYTEN. So, Congressman, I agree with your overall assessment. It is the first rule of wing-walking; you don't let go with one hand until you got firm hold of the next hand. And I am concerned we are about to let go of one before we have a firm hold on the next. So I think it is very important that we logically transition off these capabilities.

I think the efforts that General Greaves and the acquisition community have come up with to reach out to industry broadly to come up with a competitive strategy that looks at that, to use different acquisition authorities to allow them to go as fast as the acquisition process will allow them to go has been exactly the right thing to do.

But I still am concerned, is that if he does everything exactly according to plan and we get an engine by 2019, we still can't let go of the wing. And that is why the Department has come back to you and requested the ability to continue to have RD–180s for that transition period, whatever that is. And I agree with that request.

Mr. COFFMAN. General Hyten, if the supply of RD–180s were cut to less than 14 engines, what would be the practical result?

General HYTEN. There are two possible practical results. Practical result number one is that ULA can no longer be competitive in a competitive market, and, therefore, they decide that they can't compete and we move into another monopoly.

The other is that the government, because of the assured access to space requirement, decides that that can't be allowed to stand, and, therefore, for the transition period we decide to pay the premium and fly the Delta IV at a price point that will be significantly higher and pay the difference with the taxpayers' dollars.

Mr. COFFMAN. Okay.

General Hyten, what is the Department doing—and, Lieutenant General Greaves, you might want to comment on this too—what is the Department doing to ensure you are not replacing a, quote/unquote, sole source provider with a different, quote/unquote, sole source provider?

General HYTEN. Well, I think the whole approach that we are taking is to figure out how to develop the rocket propulsion system that will be available for the capabilities that we need in the future. We are going down that path so we can have that new rocket. Whether it is Vulcan with the Atlas V upper stage, or whether it is the Atlas first stage with the other pieces, we are going down that path.

And we have a much healthier industrial base now. SpaceX is certified for an element of the capabilities now, so we have SpaceX that is out there. So we have capabilities out there if we can take advantage of all of those systems, and that is what our approach is trying to do.

General GREAVES. Congressman Coffman, we initiated this in earnest last August with a request for information from industry, and we have been working with them very, very closely. And the rocket propulsion system effort that is ongoing now, step two, as we refer to it, the goal is to, based on what we gathered from industry on their capabilities across the board, to end up with an initial four potential candidates and then whittle it down to two.

So we are ensuring, based on the capability within the Nation, that we will preserve assured access to space.

Mr. COFFMAN. Assistant Secretary McFarland, would you like to comment further?

Secretary MCFARLAND. Exactly what the two gentlemen here said. The Department's look at this is that: Here we are. We have not got the intellectual capital currently inside of our government, let alone outside in industry, to do a one-for-one replacement. The RFP that is out on the street is to grow that knowledge immediately under a special type of an acquisition tool, if you would, the OTA [other transaction authority]. It has in there logical steps that would say, okay, we can now see what is the quickest, clearest, most affordable way to get to closure. And, at this time, that is, I think, the most prudent approach to doing it.

Mr. COFFMAN. Thank you, Mr. Chairman. I yield back.

Mr. ROGERS. I thank the gentleman.

The Chair now recognizes Mr. Lamborn of Colorado for any additional questions he may have.

Mr. LAMBORN. Thank you, Chairman.

And I want to follow through on a question I was asking earlier. And if I could just go down the line, starting with you, Ms. McFarland. And it has to do with questions I was asking to SpaceX.

If they haven't submitted changes for the upgrade Falcon 9, then how can it be said that their system is certified for launch or eligible for competition on the EELV?

Secretary MCFARLAND. Well, post that hearing on March the 17th, they did come in with a statement of intent and, indeed, are working with the Air Force for the heavy launch Falcon 9.

General HYTEN. And the other point I will say, sir, is that part of the transition phase of that is moving with the full-thrust engines on their Merlin capability. Now, that is a very similar process to what we went through on the Delta vehicle when we went from an RS–68 to the RS–68A. They actually work closely with us as they go through that. That is part of the normal process that we work with both Atlas and Delta over the years. We have done that on the upper stage, as well.

Once we go through and certify the system, it is basically a baseline capability. And then, as industry learns and develops new capabilities, they have to come back to us and demonstrate their changes they go through. And the lucky part is General Greaves is actually the certifier, so he can talk about all the details of that. So I will pass it to General Greaves.

General GREAVES. Well, Congressman, as General Hyten said, the Air Force has designated my position as the certification official for new entrants. And, as part of that, in assessing space access capability, we are working with them very closely. In fact, I co-chair meetings every 2 weeks with the Glenn Shotwell/Elon Musk level to assess the current status of what they have proposed, any changes that they are envisioning or have realized into their system to ensure it becomes certified in time.

So, in the end, we are well aware of proposed changes to the Falcon 9 1.1 system as part of the upgrade that was discussed in the other panel. Daily, our teams are—our organic government team, our FFRDC [Federally Funded Research and Development Center] team—are working with SpaceX to fully understand what it will take to accept those changes, whatever they may be, as a certified system.

This is no different, sir, than we have done with ULA in the past. In fact, last December, when we flew the RL10C, which is an upgraded second-stage engine, we went through a significant effort with ULA ahead of time to understand the changes of that engine, what it would do to the system, and then certify it for flight, which we did last December, and it flew very successfully for the first time.

So, today, as we speak, SpaceX has provided what changes they envision for the upgraded Falcon 9. We are, daily, in an intense effort with them to understand and hopefully certify that system.

Mr. LAMBORN. And you mentioned test flights in the case of ULA. Will test flights be part of the protocol with SpaceX?

General GREAVES. As a basis, yes, sir. But I will use the RL10C as an example. That engine was qualified as part of ULA's design and delivery process, and we flew it for the first time with an operational mission—it was a classified mission—back in December.

So it depends on the level, degree, amount, impact of the changes that we are looking at, to determine whether or not it would require a re-flight or test flight. It is no different, sir, than what we have done historically with our launch providers.

Mr. LAMBORN. And, Dr. Griffin, would you care to comment?

Dr. GRIFFIN. I would agree with General Greaves with regard to certification of new capability. In fact, I would say the idea that we fly a large number of repeated copies of rockets is something that may look true from the outside, but, truthfully, it is rare to go very long in a string without upgrading or changing something about the rocket. So you are in this continual process of evolution.

And, certainly, we don't do a non-value-added test flight, a whole separate test flight, with no payload merely because we go from an RL10B to an RL10C. You just wouldn't want to spend that kind of money. On the other hand, when you are fielding an entirely new rocket, you will do a couple of test flights, typically, before you put a valuable payload on it.

So there is an informed engineering and program management judgment that has to be applied to determine when you are willing to risk an upgrade without a test flight and when you need a test flight because the upgrade is just so big that you don't want to risk the payload.

Mr. LAMBORN. Okay.

And for a couple of clarifications, Ms. McFarland, some people have made unhelpful comments out in the public that the money from the sale of the RD–180 engines goes to, quote, "Vladimir Putin and his cronies."

Can you clarify that, please?

Secretary MCFARLAND. Congressman, I can't say where the money goes. The government buys launch services from ULA. But I can state that, on May the 6th of 2014, the U.S. Court of Claims received the opinion of the United States Department of the Treasury, the United States Department of Commerce, the United States Department of State, that the payments to NPO Energomash do not directly contravene Executive Order 13661 at this time and would inform the court in the case of such determination in the future had to be overturned.

So, from our perspective, we did exactly due diligence on this to ensure that those statements were not factual.

Mr. LAMBORN. Well, thank you for your background work and for that clarification.

And, lastly, I would like to clarify with you or possibly General Greaves, Reuters reported at one point that the contracting approach used by ULA to purchase RD–180 engines via RD Amross employed, quote/unquote, "questionable contracting practices."

Is that true?

General GREAVES. Congressman, no. It followed the standard process where the Air Force procurement contracting officer, with advice from such agencies as the DCMA [Defense Contract Management Agency], DCAA [Defense Contract Audit Agency], examined the contracting approach for both ULA and RD Amross, and they did a couple of things.

They went through and essentially did a price analysis to assess whether or not the proposed prices we were paying were within historical bounds. They also took a look at, for instance, the RS–68, what it cost to produce that engine versus what we were paying for the Russian engines.

And they correlated all this information. And there was also a cost study that was done. So, in the end, all the steps were taken. The RD–180 was procured on a fixed-price basis. So we followed all those rules, and we vehemently dispute the accuracy of that information.

Mr. LAMBORN. Okay. Thank you for that clarification.

Thank you all for being here.

Thank you, General Hyten and General Greaves, for your service to our country.

Dr. Griffin, Ms. McFarland, thank you for helping our country, as well.

Thank you, Mr. Chairman, for indulging those questions.

Mr. ROGERS. Glad to. I appreciate the questions.

I mentioned this earlier—I think it was during our first panel—that the House version of the NDAA for 2016 in this subject matter area and the Senate language is different. So this will be a question for all the witnesses.

Please comment on the impact of the current fiscal year 2016 NDAA Senate language regarding the prohibition of Russian rocket engines. Are nine engines from the 2015 to 2017 timeframe enough to maintain assured access to space and keep competition going? Why does this issue need to be addressed now?

Ms. McFarland.

Secretary MCFARLAND. No, it does not. We have in block 1–A multiple launch, competitive launch opportunities that this would not allow us to have two viable competitors for.

Mr. ROGERS. General Hyten.

General HYTEN. And then the follow-on to that is, as we go to Phase 2——

Mr. ROGERS. Well, first, do you concur with that?

General HYTEN. I concur with what Ms. McFarland just said. And it goes further than that, because my biggest concern is really when we get into Phase 2, which is the period between 18 and 22, where we have approximately 28 launches that we are going to manifest. There would be no Atlases available to compete for those launches at that time. That brings the whole discussion that we had a little while ago about the viability of ULA to get through that period—that is an even bigger concern for me as we get into Phase 2.

Mr. ROGERS. So I want to make sure that for the record we understand. Both Ms. McFarland and General Hyten are saying that the nine engines are not enough to maintain assured access to space?

General HYTEN. Yes, sir.

Mr. ROGERS. Okay.

General Greaves, you had something you wanted to say?

General GREAVES. Chairman, I concur entirely. It gets back to the entire discussion on whether or not ULA remains commercially viable to make the transition between today and 2022.

Mr. ROGERS. And that is important because?

General GREAVES. Because they need the steady stream of revenue to——

Mr. ROGERS. I mean, in the big picture, we need to have two people that can——

General GREAVES. Yes, sir. Assured access to space, yes, sir.

Mr. ROGERS. So we would be falling down on our overall goals of making sure we maintain assured access to space by having two providers.

General GREAVES. Yes, sir.

Dr. GRIFFIN. May I come in on this?

Mr. ROGERS. Dr. Griffin, absolutely.

Dr. GRIFFIN. The requirement for two providers comes more out of, if you will, my era. Back in 1986, we lost in sequence a space shuttle, a Titan, an Atlas, and a Delta. And so, by the second half of 1986, the United States had no access to space capability at all.

From among the many recovery actions taken following the loss of *Challenger,* it was determined that we would, in the expendable vehicle arena, keep two independent paths to space at all times for national security purposes. That is now—it is Presidential policy for several past administrations, and it is law. And I think, although the history is now 30 years old almost, I think we depart from that at our peril.

Mr. ROGERS. Great. You know, one of the things you will hear from the chairman of the Senate Armed Services Committee is: Well, you know, we can just rely on NASA to make sure we maintain this assured access to space.

Do you concur with that interpretation of our circumstance, Ms. McFarland?

Secretary MCFARLAND. Sir, I do not. I am going to be visiting with NASA to see what they have in their SLS [Space Launch System] vehicle. From what I understand—and I am sure General Greaves and Hyten can explain further—it is a very costly way to send up an asset given what we have to do for our mission manifest.

Mr. ROGERS. Great.

General Hyten.

General HYTEN. NASA uses Atlas and Delta for most of their scientific missions today. They are working down a couple of other paths. The Space Launch System, the SLS program, is a giant rocket, a giant rocket that is built for interplanetary exploration. It is not built to put satellites in low-earth, medium-earth, or geosynchronous orbit. So the good news is we meet with NASA, the Air Force, and the NRO [National Reconnaissance Office] all the time to talk about the partnerships. And we have great technology partnerships. But they do not have a rocket system that would meet our requirements.

Mr. ROGERS. General Greaves.

General GREAVES. Chairman Rogers, I concur with what has been said before. One additional note is that my position also functions as the flight worthiness certification official for every national security space launch. And that set of criteria that we use—in fact, I sign letters for every one of them, that criteria that we use to certify missions that are ready to support national security space, in most cases, are somewhat different than what NASA uses because their risk tolerance is, in most cases, a little higher than ours because ours are low risk. So that would be a difference if we were told to go to NASA for these engines.

Mr. ROGERS. Dr. Griffin, you used to run NASA. Do you think we ought to be relying on NASA for our assured access to space?

Dr. GRIFFIN. I don't because, in actuality, as was said earlier, NASA relies on the Department of Defense for the procurement of Delta and Atlas launch vehicles for its own robotic payloads. The larger rocket, the SLS, to which General Hyten referred, is intended for human exploration of the solar system, which I devoutly hope we will resume. But to use it for unmanned national security launches is possibly somewhat equivalent to using an aircraft carrier to transport cargo across the ocean. It would be a bit of an overkill.

Mr. ROGERS. General Greaves, what is the estimated cost of your four-part plan, including all necessary investments in engines, launch vehicles, and infrastructure? And what is the basis of that estimate?

General GREAVES. Chairman, we do not have a final estimate. And a lot of it depends on the assessment that we are doing right now. We do have funding in the 2016 PB [President's budget] to address step two and step three of the four-step process. But we are looking to see what estimates we get. And we will work that in in future budgets.

Mr. ROGERS. Great. Dr. Griffin, what are your thoughts on the cost of the Air Force's four-part plan versus funding an RD–180 replacement for existing launch vehicles and infrastructure?

Dr. GRIFFIN. As General Greaves just said, I can't know yet what the cost of the four-part plan will be. I will offer the opinion that I believe, I very strongly believe that the cheapest way for the United States to regain its national security launch independence is to re-engine the Atlas V. I said that in my testimony for the record. So I can't prejudice the outcome of a procurement process which is ongoing. Even though I am not an attorney, I know that. But I do hope that the outcome of that procurement process results in a decision to re-engine the Atlas V.

Mr. ROGERS. Ms. McFarland, what would it take to off-ramp the current Air Force plan to a path that is focused on developing an engine that complies with the law and without government development of a new launch vehicle?

Secretary MCFARLAND. I think that would be a good question to ask us after we have a chance to review what has been proposed from the Air Force's current solicitation. I think that would be a good question for the record. And I think that would be good product.

Mr. ROGERS. Great. General Greaves, you stated in your testimony that, quote, "a rocket engine specifically engineered to replace the RD–180 on the Atlas would most likely be usable only for ULA's Atlas," closed quote. However, according to press reports, Orbital ATK wanted the RD–180 so much, they sued ULA to get access to it. That suit was settled out of court. And Orbital went up with another Russian engine. But isn't it reasonable to conclude that the RD–180 would be flying on an Atlas and Antares today if Orbital had access to the RD–180?

General GREAVES. Chairman, the answer is yes. But I believe what I also said is that without significant modification to the receiving launch system, the launch vehicle—so, yes, the RD–180 could be transitioned to another launch system, but it would come with mods [modifications].

Mr. ROGERS. General Hyten, there are claims that industry doesn't need any money to get off the RD–180 or the solutions are fully funded. In your judgment, can we just rely on industry to provide us the capabilities we need for our military? In the end, will the government need to pay for its requirements?

General HYTEN. No, we can't, Congressman, in my opinion, and I think Dr. Griffin answered this well earlier when he talked about the business case that is really out there. And if you look at the business case, the business case is national security space launches, which means this is national security mission, which means we need to be able to fund the critical elements of the industrial base to make sure that is there. And, right now, that element of the industrial base is not there to support where we need to go in the future. I think it is the responsibility of the Department of Defense and the government to make sure that industrial base is there for national security.

Mr. ROGERS. Excellent. I have many more questions. But I am going to submit them to you all to get back to us for the record because it is noon, and we have worn out our welcome with you all, I am afraid. But, I very much appreciate your time and effort. You have been enormously helpful to us. And I look forward to our continuing efforts to get off this RD–180 and onto a new path of independence.

With that, this hearing is adjourned.

[Whereupon, at 12:03 p.m., the subcommittee was adjourned.]

APPENDIX

JUNE 26, 2015

PREPARED STATEMENTS SUBMITTED FOR THE RECORD

June 26, 2015

Opening Remarks of Chairman Mike Rogers
Subcommittee on Strategic Forces
HEARING ON
Assuring National Security Space: Investing in American Industry to End Reliance on Russian Rocket Engines

June 26, 2015

In the first panel, we have 5 expert witnesses from industry, who represent current and potential providers of space launch and rocket propulsion for the Evolved Expendable Launch Vehicle program.

In our second panel, we have 3 senior government officials who have responsibilities in managing and overseeing the EELV program, and we also have an expert advisor to the government on a recent launch study.

Thank you all for participating in this hearing, and providing your perspectives on this important national security issue.

This is our second hearing that we've recently conducted on space launch. We are dedicating the time to this topic because of its significance to national security. Without an effective space launch program, we lose all the advantages we gain from space capabilities. Losing space for our warfighters is not an option.

There are key policy and acquisition questions regarding the future of national security space launch that need to be addressed.

As I've said before, I'm committed to ending our reliance on Russian rocket engines for national security space launch. I believe we must end our reliance in a manner that protects our military's assured access to space and protects the taxpayer by ensuring we don't trade one monopoly for another. The House bill accomplishes this, and I look forward to the perspectives of our witnesses on the current legislation under consideration for the fiscal year 2016 NDAA.

Because we are committing to ending our reliance on Russian engines, we must invest in the United States rocket propulsion industrial base. Investment in our industry for advanced rocket engines is overdue. While we may lead in some areas of rocket propulsion, we are clearly not leading in all. This is painfully obvious considering that 2 out of the 3 U.S. launch providers we have here today rely on Russian engines. And it's not just the Russians leading the way -- according to online press reports, the Chinese may be flying a new launch vehicle on a maiden flight this summer, with similar technologies as the Russians, using an advanced kerosene engine.

The time has come to resume U.S. leadership in space, and I believe the companies here before us today can help us do that.

However, I'm concerned with the Air Force's approach in what may amount to a very expensive and risky endeavor in development of new engines, new launch vehicles, and new infrastructure. Congress has only authorized funding for the development of a rocket propulsion system. Launch vehicles are not the problem … the problem is the engine.

June 26, 2015

Testimony to the House Committee on Armed Services

Salvatore T. "Tory" Bruno, President and Chief Executive Officer, United Launch Alliance

Mr. Chairman and Members of the Committee, thank you for the opportunity to appear today to update you on efforts by United Launch Alliance (ULA) to develop a new generation of space launch capabilities to support the warfighter and our Intelligence Community. As part of my remarks, I will highlight certain geopolitical developments that have brought assured access to space to the fore, our efforts to help develop a new engine as part of our process of developing a new rocket system that will assure our nation's continued ability to deliver critical satellites to space, and will conclude by highlighting the role of competition in supporting assured access to space.

The Country and the Congress owe this Committee a great deal of thanks for approaching this subject in a responsible manner at a time when it is easy to confuse our views about Russian aggression with the need to provide for our own National Security. The current Congress did not create the situation we find ourselves in with use of a Russian engine for U.S. access to space. Half the current Congress, you Mr. Chairman and your fellow Committee members, have taken on the job of fixing this very important problem in your bill which passed with such overwhelming bipartisan support.

ULA agrees with the stated U.S. goal to rely on American-made rocket engines to ensure access to space. ULA finds itself using a Russian-made engine for its Atlas V rockets in the near term as a result of the larger U.S. post-Cold War environment of Russian proliferation threats and the de facto policy of the last three Presidential Administrations to reduce and eliminate those threats. The use of the Russian engine contained this critical space technology from being shared with rogue nations. In response to the changing international political climate, ULA is now aggressively working with domestic partners to field an American-made rocket engine for the Atlas V as soon as is practicable but still ensuring an ability to meet national security launch needs.

ULA also supports competition in the space launch business. However, if current law is not modified, America will no longer be compliant with its assured access to space policy as competition will have been unintentionally eliminated. Our efforts to field a new launch system with an American-made engine hinge on our ability to close a business case justifying the significant corporate investment we will have to make to field this system. We are unable to do this if we cannot have access to all 29 engines for which we contracted from our partner RD AMROSS prior to the outbreak of hostilities in Crimea.

I thank this Committee for its willingness to modify this current law with respect to access to the RD-180 engine in the Fiscal Year 2016 National Defense Authorization Act. Without a change to Sec. 1608 of the Fiscal Year 2015 National Defense Authorization Act, ULA will no longer be allowed to use the Atlas V's space launch capabilities, capabilities that have been integral to 96 successful launches without a failure, by as early as 2019. The Delta IV rocket, while domestically produced, is 35% more expensive to build and launch. It is not a "solution" to the problem of Atlas V's RD-180 engines, as it cannot be fabricated as quickly or as cheaply as the Atlas V. Delta is neither a cost effective solution for the DOD nor cost competitive against new entrants that feature less capable and smaller launch systems.

As you know, ULA announced it is moving forward in investing its own resources in developing a next generation domestic engine to launch our new Vulcan rocket. ULA is working with Blue Origin of Kent, Washington to develop a new American-made engine that will be powered by liquid oxygen and liquefied natural gas to power the rocket. At the same time, to reduce developmental risk, ULA is also working with Aerojet Rocketdyne of Sacramento, California on the development of the AR-1 engine; a kerosene powered rocket engine.

ULA will have enough confidence to make a down-select of the desired rocket engine in late 2016. The Vulcan launch system, powered by this new engine, will have increased performance to deliver a wider range of payloads to space. Despite congressional desire for developing a new engine by 2019, co-development of a new engine and launch system is both complex and requires sufficient schedule to perform correctly. While I am optimistic the Vulcan engine will be ready for testing in 2017 and available for commercial purposes by 2019, the Vulcan launch system will not be certified by the Air Force to support National Security Space missions until 2021 at the earliest.

As the Air Force has testified to Congress earlier this year, a new engine takes anywhere from six to eight years to develop, test, certify and have ready to use for operational missions. After an engine is developed, it must be integrated into a launch vehicle system, while manufacturing capability to mass produce the engines must be increased in a manner meeting the stringent quality assurance standards set by the DOD.

It is also important to remember that a next-generation space launch system is more than just a new engine. One cannot just plug in a new “form-fit-function” engine into a rocket and expect the system to perform. Neither engine under development by our partners would automatically work as a "drop in" replacement for the RD-180. All rockets must be designed around a specific engine, as all engines have different characteristics based on their weight, fuel types and thrust capabilities. Our objective is a Vulcan system with more thrust than the Atlas V, and we are designing our Vulcan rocket to take full advantage of this capability.

Faced with an aggressive development timeline, and the costs associated with the development of a new engine and vehicle, it is essential that ULA have access to all RD-180 engines on contract prior to the initiation of Crimea hostilities to enable an orderly transition from Atlas V to the new Vulcan rocket. The design, development and testing of a new engine and vehicle will require ULA to have access to government and private sector investment and revenue from continued Atlas V launches. With access to all 29 engines on contract authorized by the Committee in H.R. 1735, the Fiscal Year 2016 National Defense Authorization Act, ULA can eliminate U.S. dependence on the Russian engine rapidly and efficiently, with no impact to schedule and reliability, a sentiment articulated by Chairman Thornberry.

Without a change to the law, as Secretary Carter and Director Clapper note, "…loss of access to Atlas V and medium/intermediate class Delta IV capabilities, we could be faced with a multi-year gap where we have neither assured access to space nor an environment where price based competition is possible." Assured access to space requires two entities that can support the launch of the entire range of high-value space assets into space. Should Sec. 1608 of the Fiscal Year 2015 National Defense Authorization Act not be modified, America will lose assured access.

If this provision is not modified, SpaceX, a new entrant to the market, will be the only entity able to carry out medium/intermediate National Security Space lift missions but is not capable of providing all the capability of an Atlas V. In essence, Sec. 1608 grants SpaceX a monopoly for the launch of critical satellites to support warfighters. Without amending the law, ULA will be unable to move forward with providing business continuity and continued development of the U.S. designed and manufactured Vulcan launch system. Secretary of Defense Ash Carter and Director of National Intelligence James Clapper have written Congress to note they support modification of Sec. 1608 to "enable a smoother transition to new launch capabilities."

The proposed language in section 1603 of the House version of the 2016 NDAA addresses our concerns by allowing ULA to use all rocket engines contracted for prior to the outbreak of hostilities in Crimea. In contrast, the Senate version of the NDAA allows access to only two thirds of those engines – dramatically limiting our ability to compete for national security missions beyond 2018 and inhibiting a business environment conducive to an orderly transition to the Vulcan launch system.

Until this uncertainty is resolved, ULA may invest in the Vulcan rocket only on a quarterly basis, clarifying how critical legislative relief is to having the financial footing to proceed with developing the Vulcan launch system.

As I mentioned to this Committee earlier this year, ULA will retire the Delta IV medium/intermediate launch vehicle in the 2018-2019 timeframe. ULA will retain the Delta IV Heavy rocket for as long as our government customers have the need for this specialized launch capability.

I would like to take this opportunity to reiterate that development of a next generation domestic engine and vehicle is a complicated and challenging long endeavor that includes research, new design decisions, development of new technologies and manufacturing techniques, extensive testing and finally government certification. This is not a "one to two year" endeavor as some have suggested. While most knowledgeable rocket engineers estimate a new domestic rocket engine and launch system can be developed in five to seven years, we know of several examples where it has taken significantly longer. NASA's Space Shuttle program was officially announced in 1972, started orbital test flights in 1981, and ultimately started operational flights in 1982. The Space Shuttle Main Engine (SSME) development program faced several delays and problems, the most vexing of which was the high-pressure liquid oxygen pumps that experienced problems threatening success of the entire program. NASA optimistically believed the Space Shuttle could begin flights in 1977 but these unforeseen problems led to numerous engine test malfunctions and delays.

ULA's parent companies experienced similar delays firsthand. While Atlas V and Delta IV rockets were being designed, the existing US launchers, which had been developed and begun their service lives, experienced a spate of six failures over a period of 10 months in the 1998-1999 timeframe, including a shocking three consecutive Titan IV failures on very high priority national security missions. These failures resulted in the Air Force significantly increasing its oversight of the Atlas V and Delta IV programs.

Even SpaceX, who asserts that development of a replacement for the RD-180 and Atlas V should not take beyond 2019, experienced similar development and test problems with its engines and vehicles. In 2006, the Falcon 1 caught fire shortly after its launch and crashed after

34 seconds of flight[1]; in 2007, the rocket rolled after launch, was unable to reach orbit, and was unable to be recovered because its GPS locator failed[2]; in 2008, the rocket failed to separate properly, a design flaw that caused the loss of three government satellites.[3] In 2010, the Falcon 9 rolled out of control after launch because an attempted restart of the engine failed[4]; and in 2012, one of the Falcon's engines shut down midflight, resulting in the loss of a $10 million Orbcomm satellite.[5] Because of these and other development and early test problems, SpaceX was significantly delayed in providing contracted launches to NASA through the commercial cargo program. It would be best to take their aggressive estimates for development of an RD-180 replacement with skepticism.

I have been asked by some why President Kennedy was able to get to the moon within a decade, yet ULA cannot develop a new domestic engine by 2019. I would remind those using this reasoning that the United States had been developing rocket technologies like the Saturn-1 and the Mercury spacecraft well before the President's announcement. One of the greatest accomplishments in human history, leveraged heavily on preexisting propulsion technology. There is no doubt that landing on the moon was a remarkable achievement, but it would have been almost impossible to do so in that timeframe without the years of research and development that came before the announcement. Mercury flew on Redstone and Atlas missiles, Gemini on Titans, Saturn 1 on existing RL10s. The F-1 engines on Saturn V were static fired in 1959 and certified in 1964. The engines for Apollo, Mercury, and Gemini had similar

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[1] "New commercial rocket failed because of fuel leak," The Associated Press. July 18, 2006.
[2] Greg Zsidsin, "SpaceX confirms stage bump on Demoflight 2," Space Daily, March 23, 2007.
[3] "Final frontier for Star Trek star James Doohan's ashes is…bottom of the Pacific," Daily Record, August 6, 2008.
[4] Miles O'Brien, "This Week in Space," True/Slant, June 6. 2010.
[5] Damon Poeter, "Satellite aboard SpaceX ISS flight lost due to engine mishap," PC Magazine, October 12, 2012.

development spans as today. There is a misconception that it was a cold start in 1962. While ULA is also not starting from scratch with development of the Blue Origin or Aerojet Rocketdyne engine, there are still years of design and testing ahead of us. As often happens when designing technologies with this level of advancement, ULA will not have a clear new engine development timeline until full scale testing has begun. At that juncture, we will know if the design concept requires fundamental changes.

Others have asked why ULA cannot simply build the RD-180 in America, as we have a license to do so. Unfortunately, despite having the design of the engine, the rocket engine industry in the United States currently lacks the manufacturing capability and tooling capacity to easily reproduce the RD-180. Soon after the Atlas V began its operational life the government evaluated producing the RD-180 domestically but ultimately abandoned the plan due to the level of required investment. There was a conscious decision to continue to procure RD-180 engines because Russia could produce them cheaper, thereby saving the DOD money while maintaining ties to the Russian rocket industry and dissuading the supply of such technologies to rogue regimes. To build RD-180s in the United States, ULA would need to build a supplier and manufacturing network from the ground up, overcome specific manufacturing hurdles we likely are not aware of and put them through a costly test and certification process, which would not be accomplished by 2019.

The Air Force, Department of Defense, and the Intelligence Community have already expressed concern to Congress about trading one monopoly for another, a result of language in Section 1608 of the FY15 NDAA that prevents ULA from competing with the Atlas V for future national security launches until the Vulcan launch vehicle and new engine are developed. As you know, the Air Force recently certified a new entrant, SpaceX, and their Falcon 9 launch vehicle to compete for these same launches. Before the Committee and Congress potentially grant a new monopoly to SpaceX and Falcon 9, it must examine the record of SpaceX's promises and actual performance that have defined the company to date.

The space and business press is awash in stories that chronicle the history of SpaceX over-promising and under-delivering on both cost and schedule. In 2011, SpaceX claimed it could build a rocket for 75 percent less than its competitors, yet costs for SpaceX launches have climbed at an alarming rate since the company website's original quote of $61.2M for a Falcon 9 launch. Recent awards for three additional NASA International Space Station resupply missions, and military launches once the company achieved certification to launch national security payloads, have been quoted as $150M and $180M respectively[6]. In 2010, SpaceX founder Elon Musk estimated his company could build rockets for human space flights for less than $350 million. After industry observers strongly disputed this estimate as being unrealistic, Mr. Musk eventually admitted it was "naively low."[7] SpaceX fares no better in estimating schedule. In 2012, Mr. Musk stated SpaceX aimed "to begin taking people to the Space Station by 2015,"[8] and in 2014 he said he was hopeful that "the first people could be taken to Mars in 10 to 12 years."[9] Despite this, launch of the Falcon 1 was delayed by two years[10,11] and SpaceX missed five target dates for the rocket's inaugural launch.[12] The Falcon 9 launch was delayed by

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[6] www.usaspending .gov, and Ms. Shotwell testimony before the House Armed Services Committee, March 17, 2015
[7] Andy Pasztor, "SpaceX illustrates privatization risk," The Wall Street Journal, June 7, 2010.
[8] "SpaceX Dragon capsule splash lands in Pacific," Agence France Presse, May 31, 2012.
[9] Sebastian Anthony, "SpaceX says it will put humans on Mars by 2026, almost 10 years ahead of NASA," Extreme Tech, June 18, 2014.
[10] "Aerospace Daily & Defense Report," Aviation Week, February 14, 2005.
[11] "New rocket by California company fails on maiden launch," The Mercury News, March 24, 2006.
[12] Mult.

three years[13,14] and SpaceX missed seven target dates for the rocket's inaugural launch.[15] While SpaceX promises that it can significantly lower costs for the DOD and handle the full spectrum of national security launches by 2019, these promises rely on two future assumptions – the ability to reuse a rocket's first stage, which SpaceX has attempted several times now unsuccessfully, and the ability of SpaceX to develop a "heavy" variant of the Falcon. The first test flight of the Falcon Heavy has been billed as occurring later this year, but given SpaceX' s crowded manifest for the Falcon 9, that may prove impossible as the Falcon 9 Heavy requires 27 Merlin engines that may be needed for other near term launches. In addition, Space X's Merlin engine upper stage, fueled by kerosene, may be unable to inject key national security payloads into geosynchronous orbit because kerosene freezes during the time required to reach a geosynchronous location. For these reasons, we would respectfully urge Congress to carefully consider the track record of SpaceX for delivering on-time and for promised costs, given current policies in the NDAA may lead to granting them a monopoly by 2019.

While ULA serves the government and private sectors, it is most well-known for its pedigree in national security launches, which was the rationale for the creation of ULA. While SpaceX complains bitterly about "government subsidies" ULA receives to conduct national security launches, that contract pays for legitimate government requirements to provide various recurring efforts and for ULA to maintain launch infrastructure supporting two different classes of rockets at two separate launch facilities on either coast. SpaceX has been the

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[13] Patrick Peterson, "SpaceX launch reset to June 2009," Florida Today, February 29, 2008.
[14] Miles O'Brien, "This Week in Space," True/Slant, June 6, 2010.
[15] Mult.

beneficiary of significant federal and state government support itself[16]. SpaceX has relied on contracts to develop new capabilities and the use of low- or no-cost leases of previously developed launch infrastructure in Florida and California that were paid for by taxpayers. SpaceX's privately held ownership, coupled with no Defense Contract Audit Agency audits of its programs, yields little insight into transactions such as the company's purchase of $90M in SolarCity bonds, potentially putting the taxpayer at risk.

ULA would like to continue its unparalleled service to our nation's warfighter and Intelligence Community, but it can only do so if the launch vehicle replacement for Atlas V is "cost competitive". For that to happen, the following must occur in the next several years:

1. Ensure use of all 29 RD-180 engines under contract to allow ULA to compete for national security and other launches while development of Vulcan is ongoing. This means Congressional legislation to ensure ULA has access to all 29 engines for which we contracted with RD AMROSS prior to the outbreak of hostilities in Crimea. Without these engines, the business case to develop the new Vulcan launch system does not close and we will be forced from the space launch business.

2. Retirement of the Delta IV – this is necessary so multiple launch facilities and pads on the East and West coasts for Atlas V (and its variants) and Delta IV can be closed to reduce personnel, maintenance, and equipment costs. For ULA to offer reduced

[16] "Elon Musk's Companies Fueled by Government Subsidies," Los Angeles Times, June 1, 2015.

prices for launch services, it must shed infrastructure commensurate with its fewer vehicle configuration options.

3. Successful development of a new launch system that incorporates a U.S. designed and manufactured engine with enough power to meet launch requirements for all national security payloads previously handled by the Atlas V and Delta IV medium/intermediate systems. In order to cost-effectively satisfy national security and civil government requirements, as well as future commercial demands in a single family of launch vehicles, ULA must design the Vulcan to be significantly more capable than the current Atlas V. This remains the single biggest reason why simply reproducing “an American made version of the RD-180” will not suffice for ULA to be competitive as an American launch provider in the decades to come.

The fact is we are truly faced with decisions of “Rocket Science” complexity. It takes time, money, and a dedicated team of scientists and engineers to execute major developments on schedule while retaining a flawless record of mission assurance. The nation and ULA possesses those abilities and have the unblemished record of success to prove it. ULA stands ready as your partner in this task and we are happy to answer any questions you might have.

Salvatore T. "Tory" Bruno
President and Chief Executive Officer

Salvatore T. "Tory" Bruno is the president and chief executive officer for United Launch Alliance (ULA). In this role, Bruno serves as the principal strategic leader of the organization and oversees all business management and operations.

Prior to joining ULA, he served as the vice president and general manager of Lockheed Martin Strategic and Missile Defense Systems. The business is a leading provider of ballistic missile and ballistic missile defense systems, supporting U.S. Department of Defense customers, as well as the U.K. Royal Navy and Ministry of Defence. Programs included the Navy's Trident II D5 Fleet Ballistic Missile (FBM), the Air Force's Intercontinental Ballistic Missile (ICBM) Reentry Systems, and the Missile Defense Agency's Terminal High Area Altitude Defense (THAAD), Targets and Countermeasures and Common Exoatmospheric Kill Vehicle (EKV) Concept Definition. He also managed the corporation's responsibilities in Atomic Weapons Establishment (AWE) Management Limited, a joint venture that produces and safely maintains the U.K.'s nuclear weapons. He is a former member of the board of directors of Lockheed Martin U.K. Ltd.

Bruno joined Lockheed Martin in 1984. He previously served as vice president and general manager of FBM and ICBM, as vice president of the THAAD Missile, as vice president of Engineering, as chief engineer for Strategic Missile Programs, as program manager for FBM Rocket Propulsion and in engineering positions involving design and analysis for control systems of rockets and hypersonic reentry vehicles. He holds several patents.

He holds a bachelor's degree in mechanical engineering from the California Polytechnic State University, in San Luis Obispo, California, and has completed graduate courses and management programs at Harvard University, Santa Clara University, the Wye River Institute, San Jose State University and the Defense Acquisition University.

Bruno is a companion of the Naval Order of the United States, a member of the Navy League and a former member of the Board of Directors of the Silicon Valley Leadership Group. He served on the National Blue Ribbon Panel for Bettering Engineering & Science Education and as Chairman of the Diversity Council of Lockheed Martin Space Systems.

He is the author of two books that explore the organization of the medieval Knights Templar from the perspective of modern business management: "Templar Organization: The Management of Warrior Monasticism" and "Templar Incorporated." He is a recipient of the Order of Merit of the Sovereign Military Order of the Temple of Jerusalem.

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COMMITTEE ON ARMED SERVICES
U.S. HOUSE OF REPRESENTATIVES

INSTRUCTION TO WITNESSES: Rule 11, clause 2(g)(5), of the Rules of the U.S. House of Representatives for the 114th Congress requires nongovernmental witnesses appearing before House committees to include in their written statements a curriculum vitae and a disclosure of the amount and source of any federal contracts or grants (including subcontracts and subgrants), or contracts or payments originating with a foreign government, received during the current and two previous calendar years either by the witness or by an entity represented by the witness and related to the subject matter of the hearing. This form is intended to assist witnesses appearing before the House Committee on Armed Services in complying with the House rule. Please note that a copy of these statements, with appropriate redactions to protect the witness's personal privacy (including home address and phone number) will be made publicly available in electronic form not later than one day after the witness's appearance before the committee. Witnesses may list additional grants, contracts, or payments on additional sheets, if necessary.

Witness name: Salvatore Bruno

Capacity in which appearing: (check one)

○ Individual

◉ Representative

If appearing in a representative capacity, name of the company, association or other entity being represented: United Launch Alliance, LLC

Federal Contract or Grant Information: If you or the entity you represent before the Committee on Armed Services has contracts (including subcontracts) or grants (including subgrants) with the federal government, please provide the following information:

2015

Federal grant/ contract	Federal agency	Dollar value	Subject of contract or grant

2014

Federal grant/ contract	Federal agency	Dollar value	Subject of contract or grant
NRO000-15-0006	NRO	134,869,453.00	NRO Integration Companion for EELV

2013

Federal grant/ contract	Federal agency	Dollar value	Subject of contract or grant
FA8811-13-C-0003	USAF	$4,077,550,793.57	Phase 1

Foreign Government Contract or Payment Information: If you or the entity you represent before the Committee on Armed Services has contracts or payments originating from a foreign government, please provide the following information:

2015

Foreign contract/ payment	Foreign government	Dollar value	Subject of contract or payment

2014

Foreign contract/ payment	Foreign government	Dollar value	Subject of contract or payment

2013

Foreign contract/ payment	Foreign government	Dollar value	Subject of contract or payment

House Armed Services Committee (HASC)
Strategic Forces Subcommittee Hearing

"Assuring National Security Space:
Investing in American industry to end reliance on Russian rocket engines"

Testimony of Robert Meyerson
President
Blue Origin

Chairman Rogers, Ranking Member Cooper, and members of the subcommittee, thank you for the opportunity to speak before you today.

Assured access to space is a national priority and a challenge that we must meet domestically. Blue Origin is working tirelessly to deliver *the* American engine to maintain U.S. leadership in space and efficiently deliver critical national security capabilities to the men and women who rely on them for mission success. Our partnership with ULA is fully funded and offers the fastest path to a domestic alternative to the Russian RD-180, without requiring taxpayer dollars.

Established by Jeff Bezos, founder and CEO of Amazon.com, Blue Origin is focused on developing a world-class engine that will end reliance on Russia and lower the cost of the EELV program. For more than a decade we have steadily advanced our capabilities, flying five different vehicles and developing multiple liquid rocket engines all with private funding.

The U.S. industrial base now includes a number of commercial companies, like Blue Origin, that have developed significant liquid propulsion capabilities with private investment. We're spending our own money, rather than taxpayer's funds, and we are taking a "clean sheet" approach to development. We have invested in modern manufacturing equipment and processes to maximize production efficiency. We aren't burdened by unused capacity that so often gets billed back to the Government in the form of high overhead rates. As a result, we are able to out-compete the Russians, building modern, American engines on flexible production lines to serve multiple launch vehicles.

Blue is commercial and agile – a focused team with the resources to move quickly. We are vertically integrated, limiting reliance on outside suppliers and test facilities. Our development of the BE-3 hydrogen engine demonstrates the significant propulsion capability we have assembled. We have involved experts from the NASA Marshall Space Flight Center in our design cycles and risk-mitigation efforts, and we use the same processes and government-developed tools as traditional engine developers. Members of our team have held key roles on all recent liquid rocket engine development programs, including SSME, Integrated Powerhead Demonstrator (IPD), J-2X, RS-68, RS-83, RS-84, and Merlin.

Blue began developing our own engines because we couldn't find what we needed at an affordable price. Our requirements include high performance, deep throttling, restartable and reusable engines at low cost. Over the past 10 years, we have developed four different rocket engines and, in April of this year, our BE-3 engine performed flawlessly powering the maiden flight of our New Shepard space vehicle. The BE-3 is the first new American hydrogen engine to fly to space in more than a decade, after completing an extensive development program of more than 450 tests for more than 30,000 seconds of ground test time.

United Launch Alliance, America's premier launch services company, recognized the merits of our approach when they selected our BE-4 engine for their Vulcan rocket. The BE-4 improves performance at a lower cost and is already more than 3 years into development. Most importantly, it is on schedule to be qualified for flight in 2017 and ready to support the first Vulcan flight in 2019, two years ahead of any alternatives. Over 70 years of propulsion history has shown that engine development takes time. ULA and its parent companies did a great deal of due diligence before choosing the BE-4 engine. They concluded that not only could we develop the BE-4, but that we could do so on schedule and at a price that makes them more competitive over the long term. The fact that we have been in development of the BE-4 for more than three years and are on schedule gives us and ULA confidence in our ability to meet the Vulcan development timeline. Being available two years earlier means two years less reliance on the Russians.

As with any engine, an ox-rich staged combustion cycle presents significant technical challenges. For the BE-4, Blue has made conscious design choices on chamber pressure, injector design, and performance to increase margin and reduce the need for exotic materials. We also have an extensive testing program underway, testing the powerpack and injector components at our West Texas facilities, with more than 60 staged combustion tests and multiple powerpack hotfire tests conducted to date. Full engine testing is on schedule to begin by the end of next year. All of this testing is conducted on our own dedicated test stands. Having our own facilities affords us the unique advantage of testing at an accelerated pace, up to four times more throughput than in a typical government facility. In addition to dedicated test facilities, we have mitigated common schedule risks through vertical integration and multiple supply sources. We have also completed design and awarded contracts for all long-lead hardware, including critical castings, and awarded contracts for critical manufacturing equipment. The BE-4 is *the* fastest path to a domestic alternative to the Russian RD-180.

The availability of the RD-180 was the enabler for the Atlas V launch vehicle. Given its demonstrated high performance and low cost, there is no such thing as a "drop-in replacement" for the RD-180. Vehicles are designed around engines, and any new engine requires redesign and re-certification of the whole vehicle. There is no easy switch, even if the right U.S. kerosene engine actually existed today. Even if you could simply swap engines, it would result in lower performance without significant re-work to get back to current levels of performance. The BE-4 engine is the enabler for the Vulcan launch vehicle, providing increased performance over Atlas V at a lower cost.

Blue Origin supports a thoughtful and deliberate transition from the Russian RD-180, to the next generation of American launch vehicles. This means allowing ULA to acquire the engines they need to maintain Atlas V launches until transitioning to the Vulcan rocket. A gap in launches between Atlas and Vulcan undermines assured access to space and endangers national security. Blue supports the HASC FY16 NDAA language, which would allow ULA to purchase and use the RD-180s it has contracted to buy. Congress should avoid creating a new monopoly by forcing retirement of the Atlas V before the Vulcan vehicle is ready, which would be counter to the strategy of bringing competition to national security launch.

Blue is well capitalized and significant private investment has been made in the facilities, equipment, and personnel necessary to develop the BE-4. The engine is fully funded primarily by Blue with support from ULA. Most importantly, the BE-4 does not require government funding to be successful.

Overfunding engine development while leaving a gap in funding for full vehicle integration will create a deficiency in U.S. space launch capabilities. Instead of duplicating privately funded engine development efforts, the U.S. government should focus its resources on developing the next generation of launch vehicles to meet the broad spectrum of national security space launch requirements. No new engine can simply be "dropped in" to an existing launch vehicle. Launch vehicles have to be designed around their engines, and launch providers are best able to decide what engine they need.

Thank you, and I look forward to your questions.

Robert Meyerson
President of Blue Origin

Robert Meyerson is the President of Blue Origin where he has overseen the steady growth of the company since 2003. Blue is developing reusable launch systems that land vertically using rocket engines designed and built at Blue. Vehicles under development include the New Shepard system for suborbital human and research flights, as well as orbital human transportation systems. Prior to joining Blue, Rob was an Integration Manager at Kistler Aerospace, responsible for the Landing and Thermal Protection systems of a privately funded two-stage Reusable Launch Vehicle, as well as all technical activities related to Kistler's Space Launch Initiative contract with NASA's Marshall Space Flight Center. Before that, Rob spent 10 years at NASA's Johnson Space Center where he worked on the Space Shuttle and X-38/Crew Rescue Vehicle programs, leading the aerodynamic design of the Orbiter Drag Parachute, as well as the overall design, integration, and flight test of a gliding parachute for the X-38 project. He began his career as a cooperative education student at Johnson.

Rob earned a B.S. in Aerospace Engineering from the University of Michigan and a Master's Degree in Engineering Management from the University of Houston. He is an AIAA Associate Fellow and former member of the Aerodynamic Decelerator Systems Technical Committee. He is currently a Trustee at the Museum of Flight in Seattle and a member of the organization's Spaceflight Committee. He serves as an officer in the Commercial Spaceflight Federation and is also a member the University of Washington's Department of Aeronautics and Astronautics Visiting Committee.

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INSTRUCTION TO WITNESSES: Rule 11, clause 2(g)(5), of the Rules of the U.S. House of Representatives for the 114th Congress requires nongovernmental witnesses appearing before House committees to include in their written statements a curriculum vitae and a disclosure of the amount and source of any federal contracts or grants (including subcontracts and subgrants), or contracts or payments originating with a foreign government, received during the current and two previous calendar years either by the witness or by an entity represented by the witness and related to the subject matter of the hearing. This form is intended to assist witnesses appearing before the House Committee on Armed Services in complying with the House rule. Please note that a copy of these statements, with appropriate redactions to protect the witness's personal privacy (including home address and phone number) will be made publicly available in electronic form not later than one day after the witness's appearance before the committee. Witnesses may list additional grants, contracts, or payments on additional sheets, if necessary.

Witness name: Robert E. Meyerson

Capacity in which appearing: (check one)

○ Individual

◉ Representative

If appearing in a representative capacity, name of the company, association or other entity being represented: Blue Origin, LLC

Federal Contract or Grant Information: If you or the entity you represent before the Committee on Armed Services has contracts (including subcontracts) or grants (including subgrants) with the federal government, please provide the following information:

2015

Federal grant/ contract	Federal agency	Dollar value	Subject of contract or grant
N/A			

2014

Federal grant/ contract	Federal agency	Dollar value	Subject of contract or grant
N/A			

2013

Federal grant/ contract	Federal agency	Dollar value	Subject of contract or grant
N/A			

Foreign Government Contract or Payment Information: If you or the entity you represent before the Committee on Armed Services has contracts or payments originating from a foreign government, please provide the following information:

2015

Foreign contract/ payment	Foreign government	Dollar value	Subject of contract or payment
N/A			

2014

Foreign contract/ payment	Foreign government	Dollar value	Subject of contract or payment
N/A			

2013

Foreign contract/ payment	Foreign government	Dollar value	Subject of contract or payment
N/A			

HOLD UNTIL RELEASED BY THE
U.S. HOUSE OF REPRESENTATIVES

STATEMENT OF

JULIE VAN KLEECK

VICE PRESIDENT, ADVANCED SPACE AND LAUNCH SYSTEMS

AEROJET ROCKETDYNE

BEFORE THE

HOUSE COMMITTEE ON ARMED SERVICES,

SUBCOMMITTEE ON STRATEGIC FORCES

ON

ASSURING NATIONAL SECURITY SPACE: INVESTING IN AMERICAN INDUSTRY TO END RELIANCE ON RUSSIAN ROCKET ENGINES

JUNE 26, 2015

HOLD UNTIL RELEASED BY THE
U.S. HOUSE OF REPRESENTATIVES

Statement of Ms. Julie Van Kleeck before the
House Armed Services Committee, Subcommittee on Strategic Forces
June 26, 2015

"Assuring National Security Space: Investing in American industry to end reliance on Russian rocket engines"

Good morning Chairman Rogers, Ranking Member Cooper and members of the Subcommittee. It is a privilege to be here today to discuss this important national security issue. It is well past time to eliminate the use of non-allied propulsion systems for U.S. National Security Space launches. On behalf of Aerojet Rocketdyne, and its 5,000 employees nationwide, I want to thank the Congress, and especially this Committee, for recognizing the problem, and taking action. Simply stated – we have a Russian engine problem on the Atlas V rocket. The Atlas V is arguably the Nation's best and most versatile launch vehicle but the problem is that Atlas depends upon the Russian-made RD-180 booster engine. Aerojet Rocketdyne believes that the fastest, least risky and lowest cost way to remedy this problem is to develop an advanced American rocket booster engine to replace the Russian RD-180 on the existing Atlas V. With a focused competitive acquisition based on a robust public-private partnership, we firmly believe that this can be accomplished by 2019.

We thank the Committee for its leadership in authorizing funding, for fiscal years 2015 and 2016 for the Air Force to competitively develop such an engine by 2019. Aerojet Rocketdyne welcomes the opportunity to compete for that effort. Our company has the experience and capabilities to develop a state of the art, advanced technology kerosene-fueled booster engine that can be certified by 2019 and replace the RD-180, as well as serve other large booster propulsion users and future markets. To keep this engine on track for 2019, Aerojet Rocketdyne is currently self-funding development of such an engine – an engine we call "AR1." Unfortunately, over six months have passed since FY 2015 funds were appropriated for the engine development program that this Committee mandated. It appears that this engine development program may be subsumed into a lengthy new launch vehicle development cycle and a subsequent launch service acquisition.

Aerojet Rocketdyne

Aerojet Rocketdyne is a supplier of rocket, missile and satellite propulsion – solid, liquid and ion. We do not make launch vehicles; we design, develop and produce the engines and motors that power them into and through space. Aerojet Rocketdyne has been in the space propulsion business since the beginning of the Space Age. For more than 60 years, we have been on the leading edge of developing and producing advanced rocket propulsion. Aerojet Rocketdyne's first stage booster engines, upper stage engines, maneuvering thrusters and solid rocket motors have launched every American that travelled to the Moon, propelled all Space Shuttle missions, landed probes on Mars, placed national security payloads into proper orbits and provided propulsion for America's missile defense and strategic deterrent systems. Overall, Aerojet Rocketdyne has successfully powered more than 2,000 launch vehicles into space.

A Shrinking Industrial Base and an Advanced Hydrocarbon Engine Technology Gap

Since the end of the Cold War the U.S. rocket propulsion industrial base has shrunk significantly and a troubling technology gap has widened. While the U.S. leads the world in liquid oxygen – liquid hydrogen rocket engines and large solid rocket motor propulsion, the country is woefully behind in the area of liquid oxygen – hydrocarbon rocket engines. Russia is the world leader in hydrocarbon engines and a Russian produced engine, the RD-180 powers America's most versatile U.S. launch vehicle, the Atlas V. The Russian RD-180 uses an advanced staged combustion cycle that provides significant launch vehicle performance benefit; thus it is not surprising that it was selected during the EELV competition to power the Atlas. There were no equivalent engines in the U.S. inventory at that time and, sadly, that situation still exists today. Russian engines now have been imported for more than 15 years, thereby sustaining the Russian industrial base, while critically impacting the U.S. industrial base and sending hundreds of millions of dollars offshore. In addition, media reports indicate that the Chinese will debut this technology next month on a Long March launch vehicle.

Current American hydrocarbon launch vehicle engines are lower performing from virtually all aspects as compared to the Russian and Chinese staged combustion hydrocarbon engine standard. Aerojet Rocketdyne is the only U.S. company with experience developing, producing and operating a staged combustion advanced technology engine - the Space Shuttle Main Engine (RS25). This is a reusable hydrogen-based staged combustion engine that powered the Space Shuttle for 30 years and that will soon power the Space Launch System. But there are no domestically developed staged combustion hydrocarbon-fueled engines available in the United States today.

Aerojet Rocketdyne, investing its own resources, and in collaboration with the Air Force Research Laboratory, NASA, and academia, has advanced the American understanding of this critical technology over the last 20 years to a point where development and production of a globally competitive U.S. staged combustion hydrocarbon engine can occur rapidly. It is now time for the United States to aggressively pursue development, production and deployment of this technology in the U.S. launch vehicle inventory to end dependence on Russian engines and return the U.S. to leadership in globally competitive hydrocarbon engines. Aerojet Rocketdyne believes its AR1 engine can provide the United States with an advanced technology, staged combustion, hydrocarbon-fueled engine that will eliminate America's reliance on Russian engines for national security launch and close this technology gap by 2019.

Fix Atlas V's Russian Engine Problem - Quickly, Economically and with the Least Risk

Focused, sustained funding today can result in the development and certification of a U.S. rocket engine replacement for Atlas V by 2019. Rapid insertion of a replacement staged combustion kerosene-fueled engine, such as the AR1, is the lowest risk, fastest and lowest cost path to ending reliance on the Russian RD-180.

Our team is proud of AR1. It is an all U.S. designed, advanced technology, kerosene-fueled staged combustion booster engine providing over 500,000 pounds of thrust. A set of two AR1 engines coupled together form the replacement main propulsion system for the existing Atlas V – providing over one million pounds of thrust. Integration of the main propulsion system onto the existing Atlas V requires minimal changes to the launch vehicle. Using a near drop in engine replacement allows the Atlas launch vehicle to utilize the existing launch infrastructure, operations and facilities already in use for National Security Space missions today.

AR1 is not a copy of the Russian RD-180. It is being developed to match the mechanical and fluid interfaces required to integrate with the Atlas V booster and will be produced with the latest materials, advanced manufacturing techniques and the ingenuity of experienced American engineers and aerospace workers. AR1 will be superior to the RD-180 and will leapfrog the Russian technology. AR1 will be available to any U.S. large booster propulsion user and is configurable to any respective launch vehicle.

AR1 Can Be Ready by 2019

Mr. Chairman, our company can, with a focused public-private partnership, develop and certify AR1 by 2019. Aerojet Rocketdyne is able to say this with a confidence based on more than 60 years of proven experience developing and producing launch vehicle propulsion. There are a number of reasons for our confidence, including:

- Aerojet Rocketdyne has active, state of the art, liquid rocket engine production facilities that are currently delivering production engines for upcoming National Security and NASA space launches. These are engines that were first designed, developed and tested by Aerojet Rocketdyne.
- Aerojet Rocketdyne is the only domestic company that has ever designed, developed, produced, and flown rocket engines with thrusts greater than 150,000 pounds.
- Aerojet Rocketdyne has developed large liquid launch engines on similar timelines. The RS-68, the first stage booster engine on the Delta IV launch vehicle, was developed and produced on a five year schedule. It is a 700,000 pound thrust engine.
- Aerojet Rocketdyne is utilizing advanced metallurgy and additive manufacturing three dimensional printing to accelerate AR1 development and reduce cost.

- Aerojet Rocketdyne has the most advanced rocket engine development tools and processes in the industry and a proven track record of using them to continually reduce the development cycle time and bring product to market on a reliable schedule.
- Aerojet Rocketdyne fully understands the test infrastructure required to develop and certify an engine of this thrust and complexity and is actively readying these test stands to support the 2019 date.

Mr. Chairman, the biggest risk to AR1 development is continuing delay in a focused Air Force engine development program. As stated, Aerojet Rocketdyne is currently using its own funds to keep AR1 on a timeline for certification in 2019. We are ready to move forward as quickly as possible with a public-private partnership that can have AR1 available in 2019 to power an all-American Atlas V. The benefits of this public-private partnership will flow well beyond Atlas V, since the AR1 rocket engine will be a national asset available to all U.S. launch providers – current and future.

Closing

Mr. Chairman, I want to thank you again for holding this important hearing and for your and the Committee's leadership on this critical issue that is fundamental to our Nation's assured access to space for national security missions. Simply stated, America has a Russian engine problem on Atlas V, our premier launch vehicle for national security launch. With a focused U.S. staged combustion hydrocarbon engine development effort, America can rapidly eliminate its use of Russian engines on the Atlas V. A new U.S. engine, the AR1, can power an all-American Atlas V, move the United States back into a leadership position with a globally competitive hydrocarbon engine – and in doing so reinvigorate the U.S. rocket propulsion industrial base and foster a new generation of entrepreneurial American launch.

Julie A. Van Kleeck
Vice President, Advanced Space and Launch Business Unit
Aerojet Rocketdyne

Julie Van Kleeck is Vice President of the Advanced Space and Launch Business Unit for Aerojet Rocketdyne. In this position, she is responsible for space and launch propulsion research, technology development and product development programs.

Ms. Van Kleeck joined Aerojet in 1981 and was appointed to her present position in June 2013. Prior to this assignment, she was the vice president of the Space and Launch Business Unit and the Space Programs organization for Aerojet. From 2004-2005, she was the executive director for Atlas programs.

From 2001-2004, she served as executive director, Space Systems Business Develop-ment, responsible for the strategic direction, investments and growth of Aerojet's space propulsion business. From mid-1999 to October 2001, Ms. Van Kleeck managed a multi-national commercial launch vehicle project, during which she interfaced extensively with foreign launch vehicle companies and affiliated governmental agencies.

Prior to these appointments, Ms. Van Kleeck held numerous technical and management assignments at Aerojet where she focused on rocket propulsion research and development for defense, civil and commercial markets. She has been instrumental in the development of leading-edge rocket propulsion technology and products for Aerojet Rocketdyne. She has been responsible for critical product advancements in divert and attitude propulsion for kill vehicle applications and integrated propulsion systems for space exploration, which are among Aerojet Rocketdyne's most important business focus areas. In addition, as evidenced by the Atlas V solid rocket motors, Ms. Van Kleeck led the adaptation of strategic propulsion products to the commercial market place.

Ms. Van Kleeck earned her Bachelor of Science degrees in Mechanical and Aeronautical Engineering from the University of California and has extensive "hands-on" experience in fundamental rocket combustion research and development, systems engineering and liquid rocket engine and system design, development and testing. She has received numerous technical awards from Aerojet Rocketdyne and other outside organizations. Throughout the last decade, she has participated on many senior management review teams, external to Aerojet Rocketdyne, that have addressed a broad range of space and launch subjects. She is also chairperson of the European Space Propulsion board of directors.

Ms. Van Kleeck resides in Folsom, Calif. with her husband and extended family. She is an avid skier and runner.

DISCLOSURE FORM FOR WITNESSES
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Witness name: Julie A. Van Kleeck

Capacity in which appearing: (check one)

○ Individual

◉ Representative

If appearing in a representative capacity, name of the company, association or other entity being represented: Aerojet Rocketdyne, Inc.

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2015

Federal grant/ contract	Federal agency	Dollar value	Subject of contract or grant
See Attached File			

2014

Federal grant/ contract	Federal agency	Dollar value	Subject of contract or grant
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2015

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See Attached File			

U.S. GOVERNMENT CONTRACTS - 2013

Contract Number	Agency	Contract Value	Short Description
W912HQ-13-C-0037	Army Corps of Engineers	1,889,651.00	Developing a Highly Concentrated Photovoltaic Energy System
1357463	DOE	98,820.00	AERO 412 Tungsten Rods
FA8219-14-C-0002	US Air Force	28,938,704.00	Medium Class Stage III
FA8656-13-C-0235	US Air Force	15,197,216.00	BLU-129/B Production Restart
RENT-FREE STORAGE AGREEMENT	US Air Force	0	Rent Free Storage Agreement
FA8650-13-D-2335 0002	US Air Force	7,234,935.00	Medium Scale Critical Components Powerhead Hardware
FA8656-13-M-0208	US Air Force	35,296.00	TUNGSTEN SPHERES
FA8650-13-D-2335	US Air Force	0	BOA for EOST - Enhanced Operability Scramjet Technology
HR0011-13-C-0055	US Air Force	964,073.00	Hybrid Electric Drive Pump
FA8818-13-C-0026	US Air Force	10,159,932.00	RSLP
NNK13LB17P	US NASA	299,578.00	NASA UPPER STAGE STUDY
NNM13AA33C	US NASA	1,269,462.00	Thruster hardware and associated test support components
NNM13AA26C	US NASA	10,276,849.00	SLS-ABEDRR
N68936-14-C-0010	US Navy	292,077.00	SMOKE - System Mission Optimized Kinematic Enhancement
512-D30034	Veterns Admin.	2,377.52	Ni and HMA Pellets

U.S. GOVERNMENT SUBCONTRACTS - 2013

Number of Subcontracts	Agency	Total Value ($)
5	DOD	2,734,643.00
6	DOE	413,426.00
37	US Air Force	167,155,979.17
34	US Army	147,443,935.52
9	US MDA	2,339,792.00
18	US NASA	44,532,399.00
41	US Navy	250,091,096.11

U.S. GOVERNMENT CONTRACTS - 2014

Contract Number	Agency	Contract Value	Short Description
4000131648	DOE	11,459.00	DU Spheres
DE-NE0000687	DOE	7,917,741.00	Multi Mission Thermoelectric Generator (MMRTG)
B608453	DOE	124,952.00	W. FRAGS AND RODS
1438659	DOE	80,224.00	Sandia Shaped Charges
FA8650-14-C-7424	US Air Force	467,018.00	Design and Fabrication of an Ultra-Low Cost Additive Manufactured Thrust Chamber Assembly (TCA) for
FA8650-14-2-5513	US Air Force	9,998,087.00	Title III Technical Investment Agreement
FA8650-14-2-5500	US Air Force	11,750,866.00	DPA Title III Additive Manufacturing for Liquid Rocket Engines
FA8656-14-M-0095	US Air Force	35,426.98	TUNGSTEN SPHERES
W31P4Q-14-C-0090	US Army	18,507,839.00	STINGER SLEP
W31P4Q-14-C-0157	US Army	639,783.00	Army RRPR Igniters
NNC15VA86P	US NASA	10,417.00	Sample Analysis
1038465	US NASA	300,000.00	Commercial Crew Transportation Capability CLIN 3 IDIQ for Special Studies
NND14AA04C	US NASA	248,900.00	MPS-120 Flight Demo
NNS14AA11P	US NASA	86,055.00	B2 Test Stand Electrical Buildout
N68936-14-C-0035	US Navy	843,421.00	SMOKE Phase 1 plus Risk Reduction activities
N00014-14-C-0035	US Navy	614,898.00	Develop injector/manifold and inlet designs

U.S. GOVERNMENT SUBCONTRACTS - 2014

Number of SubContracts	Agency	Total Value ($)
1.00	AIR Force / NASA	62,688.00
1	Classified	9,823.00
2	DARPA	554,483.00
5.00	DOD	357,665.00
4	DOE	1,531,927.00
21	US Air Force	88,893,372.02
35	US Army	187,750,548.36
8	US MDA	11,617,487.00
13	US NASA	336,914,681.00
29	US Navy	137,029,851.23

U.S. GOVERNMENT CONTRACTS - 2015

Contract Number	Agency	Contract Value	Short Description
FA9300-15-C-0011	US Air Force	908,051.00	MAST 1.2
FA8818-13-C-0026-1	US Air Force	4,517,214.86	RSLP
W912HQ-15-C-0002	US Army	1,298,800.00	Environmentally Sustainable Liquid Gas Generator Formulations
NNS15AA43P	US NASA	350,414.00	B Common Control System Upgrade
NNC15CA07C	US NASA	18,410,242.00	NEXT-C Xenon Thruster
NNM06AB13C-1	US NASA	0	J-2X and RS-25 Engines - Basic Order Agreement

U.S. GOVERNMENT SUBCONTRACTS - 2015

Number of SubContracts	Agency	Total Value ($)
1.00	DARPA	49,184.00
2	DOD	496,905.00
4	DOE	713,972.00
9	US Air Force	20,983,916.00
13	US Army	62,735,700.22
7	US MDA	42,404,493.00
11	US NASA	58,243,473.00
16	US Navy	34,018,707.09
1	US Navy, MDA	77,500.00

FOREIGN GOVERNMENT CONTRACTS - 2013

Number of SubContracts	Foreign Government	Total Value ($)
2	Canada	5,547,286.50
1	Israel	2,280,833.39
6	Japan	1,893,308.00

FOREIGN GOVERNMENT CONTRACTS - 2014

Number of SubContracts	Foreign Government	Total Value ($)
1	Canada	148,860.90
8	Japan	2,779,793.80
1	Jordan	17,438,984.01
1	Saudi Arabia	17,438,984.01

FOREIGN GOVERNMENT CONTRACTS - 2015

Number of SubContracts	Foreign Government	Total Value ($)
1	Canada	70,984.54
2	Japan	1,122,561.00
1	Korea	2,774,762.50
4	Saudi Arabia	56,652,207.01
1	Singapore	230,417.28

House Armed Services Committee
Strategic Forces Subcommittee
26 June 2015

Testimony Presented by
Frank L. Culbertson, Jr., Capt, USN (ret)
President/Space Systems Group
Orbital ATK, Inc.

Chairman Rogers, Ranking Member Cooper and Members of the Subcommittee. Thank you for the opportunity to appear today to discuss how Orbital ATK is supporting United States national security space systems and launch vehicle programs.

Introduction

As a global leader in aerospace and defense technologies, Orbital ATK designs, builds and delivers affordable space, defense, and aviation-related systems to support our nation's warfighters as well as civil government and commercial customers in the U.S. and abroad. Our company is the leading provider of small- and medium-class space launch vehicles for civil, military, and commercial missions, having conducted more than 80 launches of such vehicles for NASA, the U.S. Air Force, the Missile Defense Agency (MDA), and other government, commercial and international customers in the last 25 years. We are also a major supplier of interceptor and target vehicles for missile defense applications, with over 200 such vehicles built in the last 20 years. The company is, in addition, the world's largest producer of solid rocket propulsion systems, having developed and manufactured over 16,000 solid rocket motors for strategic, tactical, and space applications over the last 50 years. We are proud of our past work in designing and building these launch vehicles and propulsion systems, and we are working today to continue developing cutting-edge launch capabilities that will support our nation's space goals for decades to come.

The Air Force's RPS Program

Earlier this year, the U.S. Air Force announced its EELV Phase 2 development and launch services acquisition plan. One of the initial components of this plan, beginning in FY 2015, centers on the Rocket Propulsion System (RPS) Prototype Program. We believe the Air Force's acquisition plan for RPS is well-conceived and, if supported by Congress, will be successful in providing new space launch capabilities that are affordable, reliable, and available by the end of this decade.

We strongly endorse four important principles that underpin the RPS program:

- The Air Force should enter into contracts with several launch vehicle builders who in turn would be responsible for selecting and managing propulsion system suppliers, to minimize the probability that a propulsion system would be developed that is not appropriate for vehicle operators.
- New propulsion systems developed with Air Force funds should be available on a non-discriminatory basis to all U.S. launch vehicle companies and, where feasible, should support multiple end-use applications, to potentially include strategic missiles, missile defense and human space flight as well as space launch of satellites.
- New launch vehicles and their propulsion systems supported by the Air Force should be developed in public/private partnerships with a shared investment by both the Government and Industry, in order to provide the proper incentives for highly affordable and commercially competitive vehicles and systems to be produced.
- New launch vehicles and their propulsion systems supported by the Air Force should have a high probability of conducting initial launches before 2020 and of being fully certified two years thereafter.

As both a launch vehicle builder and a propulsion system supplier, Orbital ATK is uniquely positioned to support the Air Force RPS Prototype Program. Orbital ATK has proposed both solid and liquid propulsion developments that will support a new all-American launch vehicle family that meets all the specified national security launch requirements as well as civil government, commercial and international launch needs. Our new systems will be developed in a public/private partnership with significant private investment supplementing government funding. We are confident that our alternatives will be ready to support first flights by early 2019. For our vehicles and propulsion systems, we will combine advanced solid rocket motor and liquid engine technologies to create a modular family of highly affordable and commercially competitive launch vehicles. Beyond their contribution to assured and affordable access to space, these new systems will also strengthen our country's technology base and increase its industrial utilization to benefit the U.S. Navy and Air Force's strategic missile, MDA's missile defense and NASA's human space flight programs as well.

Advanced Solid Rocket Motors

Solid-propellant rocket motors have been used in American space launch vehicles since the dawn of the space age in the late 1950's. In many cases, they have provided the primary propulsion for boost-stage and upper-stage applications, while in others, such as the Space Shuttle, Titan, Delta II and today's EELV Phase 1 they have served as supplemental propulsion along with liquid engine systems. In recent years, major design and manufacturing advances in solid motor case technologies, propellant formulation, insulator materials and other areas have resulted in higher performance, increased reliability, and enhanced affordability. At Orbital ATK, we have incorporated these new technologies in the development of six new solid rocket motors over the past seven years, completing the development of several of the motors in only two years.

As I noted earlier, solid rocket motors are critical components used by strategic missiles, missile defense interceptors, space launch vehicles, and tactical missiles for the Department of Defense, as well as launch vehicles for NASA and other government agencies and commercial customers. For example, at our production facility in Promontory, Utah, Orbital ATK is today building, and has recently successfully tested, the world's largest solid rocket motor for NASA's Space Launch System (SLS) to enable deep-space exploration. We are also on track to meet the Missile Defense Agency's needs through upgrades of solid rocket motors used in support of deployment and testing of the GMD program, ensuring all performance and schedule objectives will be achieved for this essential national defense program. Additionally, our Trident II/D5 fleet ballistic missile motors for the U.S. Navy, now in their 28th year of production, continue to support our nation's strategic deterrence objectives and are scheduled to do so for decades to come.

New Liquid Propulsion Engines

While the United States is the world's undisputed leader in development and production of solid rocket motors, the same cannot be said for our current position related to large liquid rocket engines. Fortunately, this deficiency is now being addressed by several new and innovative liquid propulsion system suppliers. In particular, we are impressed by the progress being made by Blue Origin in its BE-3 and BE-4 liquid hydrogen and methane engine programs which are being developed with private investment. Based on the progress thus far, the BE-3/BE-4 engines have the potential to advance United States liquid rocket engines far ahead of what is currently being produced overseas. And like the solid propulsion technology we are developing internally, we believe the BE engines can be available for operational use by 2019 and will be offered at commercially attractive prices.

In addition, Blue Origin has committed to be a merchant supplier of its liquid engines, making them available to all interested U.S. launch vehicle integrators. As a result, competition among vehicle companies will be promoted and production rates on BE engines will be increased, leading to lower costs for all launch service customers.

In both advanced solid rocket motors and new liquid rocket engines, the establishment of public/private partnerships will significantly reduce both initial and long-term costs to the government. And with a robust competition between two or more launch vehicle providers, there will be strong incentives to drive costs down further. However, if industry is restricted to only designing an engine to replace the RD-180 for the Atlas V, we believe significant delays and cost overruns are likely, rendering the U.S. dependent on a single launch provider for an extended period of time thus adding risk to the nations "assured access to space." This approach would contradict the best practices that have been adopted by Congress, DoD, and industry over many years for developing and manufacturing launch vehicles.

Recommendations

Chairman Rogers and Ranking Member Cooper, I appreciate this Committee's review of U.S. technology options and industrial capability for meeting our country's space launch needs. As the committee continues its deliberations on this important topic, I respectfully offer the following recommendations:

1. Fully support the Air Force's plans for development of new launch vehicles. The U.S. needs space launch systems that provide assured access to space for defense missions and that are globally competitive. The best launch systems will be developed if the government prescribes its mission requirements and then allows industry to design launch vehicles and to select propulsion systems to meet these requirements. However, if a key part of the launch vehicles, such as a particular main engine type, is prescribed by the government, industry will be severely limited in our abilities to meet these technical objectives with systems that are cost-competitive and available on expedited schedules.

2. Request that DoD conduct an updated assessment of ways that new propulsion systems can support multi-agency needs. Since the U.S. government's total annual investment in launch vehicles and propulsion systems for strategic missiles, missile defense and human space exploration substantially exceeds its funding for national security space launch, important cost synergy should be achievable by considering opportunities for propulsion commonality between different end- users. In particular, consistent with the DoD Solid Rocket Motor Industrial Base Sustainment and Implementation Plan as requested by the FY2010 National Defense Authorization Act, the Congress should continue to require coordination between the Department of Defense and NASA to ensure solid motor industrial base sustainment is considered as part of this Air Force program.

3. Encourage the Air Force to expand its EELV Phase 2 program to include consideration of medium-lift vehicles in addition to intermediate- and heavy-lift launchers. As satellite architectures continue to evolve over the next 25 to 30 years, when these new launch vehicles are operational, many types of space payloads are likely to become lighter and not require heavy launch capabilities. By ensuring the full consideration of medium-lift vehicles in its plans, DoD will provide even stronger incentives to industry to invest in a broader range of launch and propulsion systems and to further drive down launch costs.

4. Work with the Air Force to ensure a thorough but timely new launch vehicle certification process. As Wehrner von Braun once said, "We can lick gravity, but sometimes the paperwork is overwhelming." The certification process for any new launch vehicle will take time and it should not be rushed; however, it is important that the process be made as efficient as possible to ensure the timely availability of new launch vehicles.

Orbital ATK is committed to supporting our nation's assured access to space policy. Reliable, affordable, and capable space launch systems are critical to ensuring our country is prepared to maintain access to space. Through the program outlined by the Air Force, we believe that industry is best able to respond to this need. Thank you Mr. Chairman, I look forward to your questions.

Frank L. Culbertson, Jr.
President, Space Systems Group
Orbital ATK

Frank L. Culbertson, Jr. is President of Orbital ATK's Space Systems Group. Mr. Culbertson is responsible for the execution, business development and financial performance of the company's human spaceflight, science, commercial communications and national security satellite activities, as well as Technical Services to various government customers. These include some of Orbital's largest and most important programs such as NASA's Commercial Resupply Services (CRS) initiatives as well as various national security-related programs.

Previously, Mr. Culbertson served as Executive Vice President and General Manager of the Advanced Programs Group at the Orbital Sciences Corp. Prior to joining Orbital, Mr. Culbertson was a Senior Vice President at SAIC, following an eighteen-year career as a NASA astronaut. He has flown three space missions and logged over 144 days in space as shuttle commander, pilot, and station commander. His last mission launched on the Shuttle Discovery and lasted for 129 days, from August 10 until December 17, 2001, returning on the shuttle Endeavour. During that mission, he and his two Russian crewmates, lived and worked aboard the International Space Station for 125 days which included observing the attacks of September 11, 2001, as the only American in orbit at the time. Mr. Culbertson also held several key management positions within the NASA Shuttle and ISS programs and was Program Manager of the Shuttle-Mir Program.

Mr. Culbertson is a 1971 graduate of the US Naval Academy at Annapolis. He was a naval aviator, a fighter pilot, and a test pilot, and he retired from the Navy as a Captain in 1997. Mr. Culbertson has received numerous honors, including the Legion of Merit, the Navy Flying Cross, the Defense Superior Service Medal, the NAA/FAI Gagarin Gold Medal, and the NASA Distinguished Service Medal.

DISCLOSURE FORM FOR WITNESSES
COMMITTEE ON ARMED SERVICES
U.S. HOUSE OF REPRESENTATIVES

INSTRUCTION TO WITNESSES: Rule 11, clause 2(g)(5), of the Rules of the U.S. House of Representatives for the 114th Congress requires nongovernmental witnesses appearing before House committees to include in their written statements a curriculum vitae and a disclosure of the amount and source of any federal contracts or grants (including subcontracts and subgrants), or contracts or payments originating with a foreign government, received during the current and two previous calendar years either by the witness or by an entity represented by the witness and related to the subject matter of the hearing. This form is intended to assist witnesses appearing before the House Committee on Armed Services in complying with the House rule. Please note that a copy of these statements, with appropriate redactions to protect the witness's personal privacy (including home address and phone number) will be made publicly available in electronic form not later than one day after the witness's appearance before the committee. Witnesses may list additional grants, contracts, or payments on additional sheets, if necessary.

Witness name: Frank L. Culbertson

Capacity in which appearing: (check one)

○ Individual

◉ Representative

If appearing in a representative capacity, name of the company, association or other entity being represented: Orbital ATK, Inc.

Federal Contract or Grant Information: If you or the entity you represent before the Committee on Armed Services has contracts (including subcontracts) or grants (including subgrants) with the federal government, please provide the following information:

2015

Federal grant/ contract	Federal agency	Dollar value	Subject of contract or grant
ULA Atlas Components Subcontract	United States Air Force	$34,701,269	Composite launch vehicle components option exercise
ULA Atlas Subcontract Misc. Awards	United States Air Force	$49,706	Technical and production reviews; other miscellaneous

2014

Federal grant/ contract	Federal agency	Dollar value	Subject of contract or grant
ULA Atlas Components Subcontract	United States Air Force	$44,294,294	Composite launch vehicle components
ULA Atlas Subcontract Misc. Awards	United States Air Force	$338,426	Component technical/production reviews
ULA Subcontract FA8811-11-C-0001	United States Air Force	$4,580,261	ULA Atlas rocket retro motor production
ULA Subcontract FA8811-13-C-0003	United States Air Force	$270,629	Retro motor technical/production reviews
ULA Subcontract FA8811-11-C-0001	United States Air Force	$9,139,686	ULA Atlas rocket retro motor production

2013

Federal grant/ contract	Federal agency	Dollar value	Subject of contract or grant
ULA Subcontract FA8811-13-C-0001	United States Air Force	$614,615	ULA Atlas launch vehicle retro motor redesign
ULA Subcontract FA8811-11-C-0001	United States Air Force	$356,924	ULA Atlas launch vehicle retro motor rework
ULA Subcontract FA8811-13-C-0003	United States Air Force	$82,548	ULA Atlas launch vehicle retro motor production

Foreign Government Contract or Payment Information: If you or the entity you represent before the Committee on Armed Services has contracts or payments originating from a foreign government, please provide the following information:

2015

Foreign contract/ payment	Foreign government	Dollar value	Subject of contract or payment

2014

Foreign contract/ payment	Foreign government	Dollar value	Subject of contract or payment

2013

Foreign contract/ payment	Foreign government	Dollar value	Subject of contract or payment

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.

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[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.

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[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.

Jeff Thornburg
Senior Director, Propulsion Engineering
SpaceX

Jeff Thornburg is Senior Director of Propulsion Engineering at SpaceX in Hawthorne, CA and serves as the lead engineer and manager of methane engine systems including the Raptor engine development program. Jeff is responsible for the development of the propulsion hardware and facilities to lead SpaceX into the next generation of vehicles and propulsion to enable missions beyond Earth with an eye toward Mars. Thornburg also oversees flight, test, development and research operations while also supporting customer interactions, including those with NASA and the U.S. Air Force. He has a master's degree in aeronautical engineering from the U.S. Air Force Institute of Technology and a bachelor's of science in aerospace engineering from the University of Missouri-Rolla.

Prior to joining SpaceX, Jeff was a lead propulsion engineer and turbomachinery technical project manager for the J-2X engine development program at the NASA Marshall Space Flight Center. Recently, the J-2X project has successfully tested both Engine 10001 and 10002 which utilized turbomachinery designed and built during Jeff's tenure on the J-2X program. Before joining NASA, Jeff spent 4 years working for Aerojet as an engineering director for their liquid engine turbomachinery group and serving as the site manager for the Aerojet-Woodland Hills engineering office in Woodland Hills, CA.

Jeff started his career in the U.S. Air Force and served as a flight commander and aircraft maintenance officer on KC-135R tanker aircraft at MacDill AFB, FL. He was then selected to attend the Air Force Institute of Technology and earned his Master's degree in Aeronautical Engineering. Jeff was then stationed at Edwards AFB, CA where he joined the liquid rocket engine branch at the Air Force Research Laboratory and worked several component and engine technology programs that included his leadership of the joint Air Force-NASA Integrated Powerhead Demonstration engine which was the world's first hydrogen full-flow staged combustion cycle engine demonstration. Since his first assignment to Edwards AFB, Jeff has been very fortunate to have a career that has associated him with almost all liquid engine technology development programs since the development of the Space Shuttle Main Engine.

Jeff has received numerous Air Force and NASA awards including a NASA Space Flight Awareness award, the NASA Made It Happen award, the NASA Stennis Space Center Propulsion Test Director's Leadership Award, and was an Air Force Research Laboratory Technical Program Manager of the Year. Jeff and his wife, Jessica, live in El Segundo, CA with their daughter Jameson.

DISCLOSURE FORM FOR WITNESSES
COMMITTEE ON ARMED SERVICES
U.S. HOUSE OF REPRESENTATIVES

INSTRUCTION TO WITNESSES: Rule 11, clause 2(g)(5), of the Rules of the U.S. House of Representatives for the 114th Congress requires nongovernmental witnesses appearing before House committees to include in their written statements a curriculum vitae and a disclosure of the amount and source of any federal contracts or grants (including subcontracts and subgrants), or contracts or payments originating with a foreign government, received during the current and two previous calendar years either by the witness or by an entity represented by the witness and related to the subject matter of the hearing. This form is intended to assist witnesses appearing before the House Committee on Armed Services in complying with the House rule. Please note that a copy of these statements, with appropriate redactions to protect the witness's personal privacy (including home address and phone number) will be made publicly available in electronic form not later than one day after the witness's appearance before the committee. Witnesses may list additional grants, contracts, or payments on additional sheets, if necessary.

Witness name: Jeffrey Thornburg

Capacity in which appearing: (check one)

○ Individual

◉ Representative

If appearing in a representative capacity, name of the company, association or other entity being represented: Space Exploration Technologies Corp.

Federal Contract or Grant Information: If you or the entity you represent before the Committee on Armed Services has contracts (including subcontracts) or grants (including subgrants) with the federal government, please provide the following information:

2015

Federal grant/ contract	Federal agency	Dollar value	Subject of contract or grant

2014

Federal grant/ contract	Federal agency	Dollar value	Subject of contract or grant
FA8811-14-C-003	U.S. Air Force	$ 4,252,654	EELV Early Integration Studies
NNK14MA74C	NASA	$1,115,023,687	Commercial Crew Transportation Capability
	Subcontract to The Boeing Company		Coupled loads analysis for TO-128
	Subcontract to Northrop Grumman Systems Corporation		Launch reservation agreement

2013

Federal grant/ contract	Federal agency	Dollar value	Subject of contract or grant
NNK13MA08C	NASA	$9,569,525	Certification Products Contract
NRO000-14-C-0049	NRO	$5,383,519	Leading Edge Integration

Foreign Government Contract or Payment Information: If you or the entity you represent before the Committee on Armed Services has contracts or payments originating from a foreign government, please provide the following information:

2015

Foreign contract/ payment	Foreign government	Dollar value	Subject of contract or payment
LuxGovSat S.A.	Luxembourg	12,000,000.00	Launch Services
Qatar Satellite Company	Qatar	$19,855,147.00	Launch Services
Comision Nacional de Actividades Espaciales	Argentina	$41,851.00	Launch Services
ArabSat	Saudi Arabia (Arab League)	$8,760,000.00	Launch Services

2014

Foreign contract/ payment	Foreign government	Dollar value	Subject of contract or payment
National Applied Research Laboratory - National Space Orga	Taiwan	1,932,262.50	Launch Services
Qatar Satellite Company	Qatar	$16,050,000.00	Launch Services

2013

Foreign contract/ payment	Foreign government	Dollar value	Subject of contract or payment
Comision Nacional de Actividades Espaciales	Argentina	25,105,872.48	Launch Services

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U.S. HOUSE OF REPRESENTATIVES

STATEMENT OF

HON KATHARINA MCFARLAND

ASSISTANT SECRETARY OF DEFENSE
(ACQUISITION)

BEFORE THE

HOUSE COMMITTEE ON ARMED SERVICES

SUBCOMMITTEE ON STRATEGIC FORCES

ON

ASSURING NATIONAL SECURITY SPACE: INVESTING IN AMERICAN INDUSTRY
TO END RELIANCE ON RUSSIAN ROCKET ENGINES

JUNE 26, 2015

HOLD UNTIL RELEASED BY THE
U.S. HOUSE OF REPRESENTATIVES

Chairmen Rogers, Ranking Member Cooper, and distinguished members of the Committee, I appreciate the opportunity to appear before the subcommittee and testify about Assuring National Security Space: Investing in American industry to end reliance on Russian rocket engines.

Assured Access to Space

Our defense space capabilities are central to our national security. This policy is codified in 10 U.S.C. 2273, which requires the Department of Defense to sustain at least two space launch vehicles capable of delivering into space any national security payload, while also maintaining a robust space launch infrastructure and industrial base. We must not allow this to be compromised due to the current uncertain budgetary and programmatic environment. The Department's Evolved Expendable Launch Vehicle (EELV) program has had an unprecedented record of 83 successful launches since 2002. A critical element of the EELV program's success to date has been the availability of two families of launch systems, the Delta IV and Atlas V systems provided by the Joint Venture of Boeing and Lockheed Martin - United Launch Alliance (ULA). Both systems are capable of supporting the DoD's launch requirements such that, in the event one capability is not available due to the need to resolve an issue, the other is able to continue operations and meet the Nation's space launch needs.

Enabling Competition

In the late 2000's, the Department anticipated the emergence of New Entrant launch service providers and foresaw the opportunity to reintroduce competition into EELV for the first time since 2006. The Under Secretary of Defense for Acquisition, Technology & Logistics approved the Air Force's strategy to reintroduce competition into the EELV program in November 2012 and placed the EELV program on a path to competition by 2015 and competition on all National Security Space (NSS) launches by 2018. This competition was expected to be between launch service providers such as Space Explorations Technology Corp. (SpaceX) with its Falcon 9v1.1 launch system and ULA with their most cost effective medium launch capability, the Atlas V which uses the Russian RD-180 engine. Concerns about reliance on Russia for rocket engines or propulsion systems accelerated with Russian aggression in the Ukraine. This concern resulted in the passage of section 1608 of the Carl Levin and Howard P. "Buck" McKeon National Defense Authorization Act for Fiscal Year 15 (Public Law 113-291)

(FY15 NDAA) which prohibits the Department from awarding a contract for the procurement of launch services under the EELV Program that is carried out using rocket engines designed or manufactured in the Russian Federation.

The medium and intermediate class payloads traditionally serviced by Atlas V and Delta IV represents the bulk of our current NSS launch requirement. Even with SpaceX now eligible for award of launch service contracts, the Falcon 9v1.1 is certified to four of the eight NSS orbit requirements and therefore cannot currently meet all of the DoD's medium to intermediate class spacecraft launch needs. To avert segmenting the launch market, with sole source providers individually servicing portions of the medium/intermediate and heavy market segments, the Department developed a strategy that preserves assured access to space while rapidly transitioning from use of the Russian RD-180 engine. To replace the RD-180, and ensure a domestically produced rocket, it takes about seven years with technologically mature components to build and re-certify a launch system with a new engine. The transition has already started and will complete during the next phase of the EELV program, which is known as "Phase 2" and is for procurements to be awarded starting in FY18. The Department's path will remove the Department from reliance on Russian engines, while maintaining assured access to space.

Rocket Propulsion System (Engine) Replacement

In August 2014, the Air Force released a Request for Information (RFI) to industry soliciting their feedback on approaches to transitioning from use of the RD-180. Industry responses supported the Department's strategy to invest with industry to transition off the RD-180 engine and provide launch capabilities able to support NSS requirements. Support, commitment, and capability to achieve the ultimate objective of access to two viable, domestically designed and produced propulsion systems in accordance with 10 U.S.C 2273 and National Space Transportation Policy by the end of EELV Phase 2 procurement in FY22 is clearly visible by Industry respondents. However despite this support, in order to maintain competition and launch schedule during the Phase 2 procurement, the Department determined and recognized it required continued use of the Atlas V necessitating that DOD be allowed to use the remaining RD-180 engines from ULA's 2012 purchase agreement during the transition period to Phase 3 procurement.

The Department leverages commercial space transportation services to meet its requirements, whenever possible, as mandated by the Commercial Space Act (51 U.S.C 50131) and currently procures launch services for NSS launches. The Department does not take ownership of any launch vehicle hardware and plans to continue using the launch service approach to manage the transition from use of the RD-180.

Statutory Challenges

Subsequent to the Department electing to pursue the launch services approach, the FY15 NDAA was enacted. It contains provisions representing significant challenges to the transition strategy.

Section 1604 of the FY15 NDAA directs the Secretary of Defense to develop a next generation rocket propulsion system and the accompanying Joint Explanatory Statement notes the provision is not an authorization of funds for the development a new launch vehicle.

Section 1608 of the FY15 NDAA prohibits the award of a contract that is carried out using rocket engines designed or manufactured in the Russian Federation. This prohibition, strictly applied, would prematurely curtail the Department's access to the RD-180 engine and thus the Atlas V launch system. ULA's announcement that it plans to phase out its non-price competitive medium and intermediate Delta IV variants after 2018 further complicates matters as the payloads that these two systems service represents the bulk of our NSS launch manifest. Even with the SpaceX Falcon 9v1.1 now certified, the Department is concerned that with the loss of access to Atlas V and phase-out of the medium/intermediate class Delta IV vehicle, we will be in jeopardy of not meeting the assured access to space requirements of 10 U.S.C. 2273. Section 1608 as enacted, creates a multi-year gap without at least two price competitive launch providers servicing medium to intermediate class missions, presuming that SpaceX is able to handle all of the Department's launch needs, and trades one sole source provider for another on medium and some intermediate NSS launches.

To avoid this unacceptable situation and to enable an orderly transition, the Department submitted Legislative Proposal #192 requesting that section 1608 be amended to permit a contractor to use a rocket engine designed or manufactured in the Russian Federation when performing a contract for NSS launch activities under the EELV program if prior to February 1, 2014, the contractor had fully paid for the rocket engine or had entered into the contract under which the Russian rocket engine would be procured. The Department believes that this would enable ULA to continue to participate in competitions for EELV launch services contracts proposing the use of the Atlas V launch vehicle well into the next decade. If enacted, this legislative proposal coupled with the addition of the newly certified SpaceX Falcon 9v1.1, enables the Department to minimize impacts to its space-based capabilities while industry completes the transition to using domestically designed and produced propulsion systems.

The Department greatly appreciates the Strategic Forces subcommittee's support of Legislative Proposal #192 and looks forward to working with Congress and the Defense committees on other statutory concerns as the FY16 budget authorizations and appropriations language is debated.

Way Ahead

The Air Force is currently moving forward in compliance with section 1604 of the FY15 NDAA. Their strategy is a four step, incremental approach transitioning to domestic propulsion while assuring access to space. Each step gathers requisite programmatic, industrial base and technical information to inform follow on steps. This is necessary for what is a highly cost uncertain program in a highly uncertain, budget constrained environment.

Step 1, started last year, matures the technology to reduce engine development technical risk. The Air Force has obligated approximately $50M toward this effort and will invest an additional $45-50M in the next few months.

Step 2 initiates investment in Rocket Propulsion Systems. The Air Force plans to enter into other transaction agreements with propulsion system or launch system providers that co-invest in on-going domestic propulsion system development efforts maximizing the highest probability of success. On June 2, 2015, the Air Force released a Request for Proposals (RFP) seeking to facilitate the development of domestically produced Rocket Propulsion System (RPS) prototypes, as early as possible, that will enable the associated domestic Evolved Expendable Launch Vehicle class launch system designs to be developed or matured, and will ensure full Government access to appropriate Intellectual Property (IP) rights.

In Step 3, the Air Force plans to enter into other transaction agreements with launch system providers to provide domestically powered launch capabilities, leveraging results of Step 2.

In Step 4, the Air Force intends to compete and award contracts with certified launch providers for launch services. These providers will on-ramp the systems developed under shared investment while off-ramping legacy systems, including those using Russian RD-180 engines.

We anticipate that solutions proposed during Step 2 and 3 will range from new launch capabilities and infrastructure to evolution of existing launch capabilities and infrastructure. For those solutions selected and carried forward into subsequent steps, the Department will work closely with Congress to ensure they are appropriately funded in future Department budget requests.

Conclusion

As the Air Force refines its approach to procuring future EELV missions, I would like to re-emphasize the Department's commitment to transitioning off the RD-180 engine in the most efficient, expeditious and affordable manner possible. The goal of the Department in spacelift has been, and continues to be, maintaining a high standard of Mission Assurance for NSS requirements while leveraging competition to make spacelift more affordable. The transition from the use of Russian manufactured propulsion systems is a difficult challenge. The Department will continue to work with Congress and industry to execute a cost-effective and technically viable plan to end the Department of Defense's use of Russian manufactured rocket propulsion systems.

Katrina G. McFarland
Assistant Secretary of Defense (Acquisition)

Katrina McFarland is the Assistant Secretary of Defense (Acquisition).

In this role, she is the principal adviser to the Secretary of Defense and the Under Secretary of Defense for Acquisition, Technology and Logistics on matters relating to acquisition.

Previously, she served as the President of the Defense Acquisition University (DAU) where she continued to build DAU's outstanding reputation as the DoD's primary learning institution while overseeing the development and expansion of acquisition curriculum and supporting learning opportunities for over 150,000 members of the Defense Acquisition Workforce. Under her leadership, DAU provided practitioner training, career management, and services to enable the acquisition, technology, logistics, and requirements community to make smart business decisions and deliver timely and affordable capabilities to the Warfighter. This included addressing the ever changing Defense Acquisition climate as required by the Under Secretary of Defense's (Acquisition, Technology and Logistics) "Better Buying Power" initiatives, and the recent National Defense Authorization Act directions and guidance.

Prior to joining DAU, Mrs. McFarland was the Director for Acquisition for the Missile Defense Agency (MDA)—a position she held since May 2006. As MDA's principal acquisition executive, Mrs. McFarland advised the Director of MDA on all acquisition, contracting and small business decisions. During her tenure, Mrs. McFarland's advice led to over $37 billion of sole source procurement activity being opened up to competition. Additionally, her successful efforts to centralize the acquisition of knowledge-based services enabled small businesses to compete for almost half of the MDA's knowledge based service, while reducing related procurement costs. Other core responsibilities included the development of process activities and program policy associated with the execution of the single integrated Ballistic Missile Defense System research, development and test program, and establishment of the Baseline Execution Review to ensure an integrated program execution of the BMDS occurred across the baselines of schedule, cost, performance, contracting, test and operational delivery.

Mrs. McFarland began her civil service career in 1986 as a general engineer at Headquarters Marine Corps where she was accredited as a Materials, Mechanical, Civil and Electronics Engineer. In 1990, she was hired by the Department of National Defense, Ottawa, Ontario, where she executed Procurement Head of Electronics duties. In 1992, Mrs. McFarland returned to the Marine Corps—this time, Marine Corps System Command—where she was responsible for the acquisition of the USMC Aviation and Ground Command and Control, radars/sensors, air defense, Combat ID and Cooperative Engagement Capability initiatives. She continued to serve the Corps through February 2005, when she concluded her duties as the Director, Battle Management and Air Defense Systems (BMADS).

Mrs. McFarland's accolades and accomplishments are far-reaching. She has received awards for her efforts in the joint arena of CEC, C2 and Theater Missile Defense integration and received recognition for her work from agencies including Government Computing News. Her articles have been published in the Military Operations Research Society, American Society for Computer Simulation, and the International Aeronautical Engineering Societies Proceedings. She has received the Presidential Meritorious Executive Rank Award for 2011, the Secretary of Defense Medal for Meritorious Civilian Service Award, the Department of the Navy, United States Marine Corps, Commendation Medal for Meritorious Civilian Service, DAWIA Level-III-certified in program management, has a professional engineer license and has attained her PMP certification.

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SUBCOMMITTEE ON STRATEGIC FORCES
HOUSE ARMED SERVICES COMMITTEE
UNITED STATES HOUSE OF REPRESENTATIVES

DEPARTMENT OF THE AIR FORCE

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

SUBJECT: Assuring National Security Space: Investing in American Industry to End Reliance on Russian Rocket Engines

STATEMENT OF: General John E. Hyten
Commander, Air Force Space Command

June 26, 2015

NOT FOR PUBLICATION UNTIL RELEASED BY THE
SUBCOMMITTEE ON STRATEGIC FORCES
HOUSE ARMED SERVICES COMMITTEE
UNITED STATES HOUSE OF REPRESENTATIVES

Introduction

Chairman Rogers, Ranking Member Cooper, and distinguished Members of the Subcommittee, it is an honor to appear before this Subcommittee once more to discuss assured access to space. It has been my distinct privilege to lead and represent the 38,000 dedicated men and women of Air Force Space Command (AFSPC), serving at 134 locations around the world, who provide foundational space capabilities to this Nation. It is through their efforts we are able to secure, defend, and enable space capabilities vital to our way of life and integral to national security.

As this Subcommittee is well aware, space assets impact the breadth of our daily lives. For example, our Global Positioning System is used in banking, global commerce, agriculture, and even in the distribution of utilities from our power companies. We have come to depend on our satellites for communications, remote sensing to deter against nuclear war, forecast weather, and manage our critical natural resources. No question, space capabilities are integral to every aspect of our Nation's defense. Today, military planners optimize the use of space capabilities to enhance the effectiveness of our military forces whether they are in training, engaged in humanitarian assistance, or conducting combat operations. Space isn't just an enabler for the other domains; it directly impacts the calculus of national security.

These capabilities however, are impossible unless we maintain our assured access to space and maintain a vigorous space launch industrial base. The loss of assured access to space would be extremely damaging to national security and without it, Air Force Space Command cannot accomplish one of our highest priority missions.

Assured Access to Space

With the Nation's deep reliance on space capabilities, assured access to space remains one of our highest priorities. It is essential we sustain a reliable capability to deliver national security satellites to space. The Evolved Expendable Launch Vehicle (EELV) team continues an unprecedented string of successful national security space (NSS) launches, carrying some of our most precious spacecraft into orbit including global navigation and timing, missile warning, communications, weather, and intelligence. In 2014, the Atlas V and Delta IV launch vehicles executed 13 launches, nine of which supported NSS missions, and with the launch of the AFSPC-5 mission on May 20, 2015, extended the record of EELV total launch successes to 83.

New Engine Replacement

A complex international supply chain fills gaps in domestic production capability for some launch vehicle components, but has led to the exposure of certain key components that are reliant on potentially non-cooperative nation states. Chief of these is the Russian RD-180 rocket engine in ULA's Atlas V. Within the context of assured access to space, it is absolutely critical we move expeditiously to eliminate reliance on the RD-180. Uncertainty regarding its future availability results in increased risk to our national security space posture.

Therefore, the Air Force has developed a four-step plan to transition off the RD-180, which will preserve our assured access to space and mission assurance while we maintain our objective to reintroduce competition. First, which started last year, is to mature the technology to reduce the technical risks going forward. We have obligated approximately $50 million toward this effort and will invest an additional $45-50 million in the next 6 months. Second is to initiate investment in Rocket Propulsion Systems, in compliance with the FY2015 NDAA. We will award multiple contracts with propulsion system or launch system providers to partner with on-going investments in domestic propulsion systems. Third, we will continue our public-private partnership by entering into agreements with launch system providers to provide domestically powered launch capability for the Nation. Finally, we will compete and award contracts with certified launch providers for launch services for 2018 and beyond. These providers will on-ramp the systems developed under our shared investment while off-ramping legacy systems, which use Russian engines. With this approach, we are confident that we can partner with American industry to develop a domestic propulsion system, integrate it into a launch system, reintroduce competition to national security launch, and transition off the reliance of the Russian RD-180.

However, it is important to emphasize the fact that any new engine still has to be integrated into a new space launch system. More importantly, we do not want to be in a position where significant resources have been expended on a rocket engine and no commercial provider has built the necessary rocket. Of course, even if that rocket is significantly comparable to any of our existing launch vehicles, integrating a new engine still requires comprehensive testing and certification which will likely take another year or two. For this reason, I support the recent Department of Defense request to Congress that allows ULA to complete the 2012 purchase agreement they made for additional RD-180s. Fulfilling the terms of that agreement will allow them to compete in the next competitive phase until a new rocket is ready to deliver capabilities into space. Without access to the RD-180 during that time, we severely limit our assured space access, undermine the competition we have worked so diligently to enable and will have traded one monopoly for another in the medium and intermediate vehicle classes.

Launch as a Service

Our approach to space lift has fundamentally changed over the last decade. The Air Force no longer owns the vehicles that we launch; therefore, we purchase access to space as a service. Industry is now investing large amounts of private capital in developing new engines and launch vehicles and we are collaborating closely with them to determine how best to invest in public-private partnerships toward U.S.-made propulsion systems.

A robust and diverse industrial base that can deliver launch capability safely and at a competitive price is central to assuring access to space. Nevertheless, launch is a risky and difficult business. We must encourage a business model among our industry partners that is stable, predictable, and able to anticipate launch failure without collapsing. It will be a significant challenge, but we believe with the efforts and ingenuity of our government and industry teams, it is possible to develop an American engine by 2019 and have two commercially-viable, certified, launch providers by the end of FY 2022.

Conclusion

Access to space has not only fundamentally changed warfare, but also our Nation's way of life, providing essential assets for the global community and world economy. However, our space capabilities are merely an illusion if we cannot deploy space based capability. Therefore, we must ensure unfettered delivery of effects such as satellite communications, missile warning, position, navigation and timing, environmental sensing and supporting ground architecture.

I remain committed to sustaining the highest levels of mission assurance and ensuring our objective to safely and reliably launch national security payloads on a schedule determined by the needs of the national security space enterprise. This requires a collective responsibility to safeguard the health of our Nation's space industry, expand the launch business to encourage new entrants into the market, and end reliance on foreign rocket propulsion systems.

I thank the Subcommittee for their support and look forward to our continued partnership to provide resilient, capable, and affordable space capabilities for the Joint Force and the Nation.

General John E. Hyten
Commander, Air Force Space Command

Gen. John E. Hyten is Commander, Air Force Space Command, Peterson Air Force Base, Colorado. He is responsible for organizing, equipping, training and maintaining mission-ready space and cyberspace forces and capabilities for North American Aerospace Defense Command, U.S. Strategic Command and other combatant commands around the world. General Hyten oversees Air Force network operations; manages a global network of satellite command and control, communications, missile warning and space launch facilities; and is responsible for space system development and acquisition. The command comprises approximately 40,000 space and cyberspace professionals assigned to 134 locations worldwide. General Hyten also directs and coordinates the activities of the headquarters staff.

General Hyten attended Harvard University on an Air Force Reserve Officer Training Corps scholarship, graduated in 1981 with a bachelor's degree in engineering and applied sciences and was commissioned a second lieutenant. General Hyten's career includes assignments in a variety of space acquisition and operations positions. He served in senior engineering positions on both Air Force and Army anti-satellite weapon system programs.

The general's staff assignments include tours with the Air Force Secretariat, the Air Staff, the Joint Staff and the Commander's Action Group at Headquarters Air Force Space Command as Director. He served as mission director in Cheyenne Mountain and was the last active-duty commander of the 6th Space Operations Squadron at Offutt AFB, Nebraska. In 2006, he deployed to Southwest Asia as Director of Space Forces for operations Enduring Freedom and Iraqi Freedom. General Hyten commanded the 595th Space Group and the 50th Space Wing at Schriever AFB, Colo. Prior to assuming command of Air Force Space Command, he served as the Vice Commander, Air Force Space Command.

EDUCATION
1981 Bachelor's degree in engineering and applied sciences, Harvard University, Cambridge, Mass.
1985 Master of Business Administration degree, Auburn University, Montgomery, Ala.
1985 Distinguished graduate, Squadron Officer School, Maxwell AFB, Ala.
1994 Distinguished graduate, Air Command and Staff College, Maxwell AFB, Ala.
1999 National Defense Fellow, University of Illinois, Champaign, Ill.
2011 Senior Managers in Government Course, Harvard University, Cambridge, Mass

ASSIGNMENTS
1. November 1981 - December 1985, Configuration Management Officer and Chief, Configuration Management Division, Automated Systems Program Office, Gunter AFB, Ala.
2. December 1985 - July 1989, Chief, Software Development Branch; and Chief, Engineering and Acquisition Division, Space Defense Programs Office, Los Angeles AFB, Calif.
3. August 1989 - July 1990, Special Adviser to the U.S. Army, Kinetic Energy Anti-Satellite Program Office, U.S. Army Strategic Defense Command, Huntsville, Ala.
4. July 1990 - August 1991, Deputy for Engineering, Strategic Defense Initiatives Program Office, Los Angeles AFB, Calif.
5. August 1991 - May 1992, Executive Speechwriter and Systems Analyst, Assistant Secretary of the Air Force (Acquisition), the Pentagon, Washington, D.C.
6. May 1992 - July 1993, Program Element Monitor, Advanced Technology Programs, Assistant Secretary of the Air Force (Acquisition), the Pentagon, Washington, D.C.
7. July 1993 - June 1994, Student, Air Command and Staff College, Maxwell AFB, Ala.

8. July 1994 - June 1996, Mission Director, Space Operations Officer, and Chief, Command Center Training, U.S. Space Command, Cheyenne Mountain Air Force Station, Colo.
9. August 1996 - August 1998, Commander, 6th Space Operations Squadron, Offutt AFB, Neb.
10. August 1998 - June 1999, National Defense Fellow, University of Illinois, Champaign
11. June 1999 - June 2001, Operations Officer, and Chief, Space Branch, Defense and Space Operations Division, Deputy Director for Operations (Current Readiness and Capabilities), J3, Joint Staff, the Pentagon, Washington, D.C.
12. June 2001 - June 2003, Chief, Space Control Division, Directorate for Space Operations and Integration, Deputy Chief of Staff for Air and Space Operations, Headquarters U.S. Air Force, Washington, D.C.
13. June 2003 - July 2004, Director, Commander's Action Group, Headquarters Air Force Space Command, Peterson AFB, Colo.
14. July 2004 - April 2005, Commander, 595th Space Group, Schriever AFB, Colo.
15. April 2005 - May 2007, Commander, 50th Space Wing, Schriever AFB, Colo. (May 2006 - October 2006, Director of Space Forces, U.S. Central Command Air Forces, Southwest Asia) 16. May 2007- September 2009, Director of Requirements, Headquarters Air Force Space Command, Peterson AFB, Colo.
17. September 2009 - February 2010, Director, Cyber and Space Operations, Directorate of Operations. Deputy Chief of Staff for Operations, Plans and Requirements, Headquarters U.S. Air Force, Washington, D.C.
18. February 2010 - August 2010, Director, Space Acquisition, Office of the Under Secretary of the Air Force, the Pentagon, Washington, D.C.
19. September 2010 - May 2012, Director, Space Programs, Office of the Assistant Secretary of the Air Force for Acquisition, Washington, D.C.
20. May 2012 - Aug 2014, Vice Commander, Air Force Space Command, Peterson AFB, Colo.
21. Aug 2014 – present, Commander, Air Force Space Command, Peterson AFB, Colo.

SUMMARY OF JOINT ASSIGNMENTS

1. July 1994 - June 1996, Mission Director, Space Operations Officer, and Chief, Command Center Training, U.S. Space Command, Cheyenne Mountain Air Force Station, CO., as a major
2. June 1999 - June 2001, Operations Officer, and Chief, Space Branch, Defense and Space Operations Division, Deputy Director for Operations (Current Readiness and Capabilities), J3, Joint Staff, the Pentagon, Washington, D.C., as a lieutenant colonel

BADGES

Master Space Operations Badge
Master Cyberspace Operator Badge

MAJOR AWARDS AND DECORATIONS

Distinguished Service Medal
Legion of Merit with oak leaf cluster
Defense Meritorious Service Medal with two oak leaf clusters
Meritorious Service Medal with four oak leaf clusters
Air Force Commendation Medal
Army Commendation Medal
Joint Staff Achievement Medal
Air Force Achievement Medal

OTHER ACHIEVEMENTS

1991 Recipient of the William Jump Award for Excellence within the Federal Government
1998 Recipient of a Laurels Award, Aviation Week and Space Technology Magazine
2009 Gen. Jerome F. O'Malley Distinguished Space Leadership Award

PUBLICATIONS
"A Sea of Peace or a Theater of War: Dealing with the Inevitable Conflict in Space," The Program in Arms Control, Disarmament, and International Security Occasional Paper, University of Illinois, 2000 "A Sea of Peace or a Theater of War," Air and Space Power Journal, Air University Press, 2002
"Moral and Ethical Decisions Regarding Space Warfare," with Dr. Robert Uy, Air and Space Power Journal, Air University Press, 2004

EFFECTIVE DATES OF PROMOTION
Second Lieutenant Aug. 23, 1981
First Lieutenant Aug. 23, 1983
Captain Aug. 23, 1985
Major May 1, 1993
Lieutenant Colonel Jan. 1, 1997
Colonel June 1, 2002
Brigadier General Oct. 1, 2007
Major General Nov. 10, 2010
Lieutenant General May 18, 2012
General Aug. 15, 2014

(Current as of August 2014)

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

DEPARTMENT OF THE AIR FORCE

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

SUBJECT: Assuring National Security Space: Investing In American Industry to End Reliance on Russian Rocket Engines

STATEMENT OF: Lt General Samuel A. Greaves
Air Force Program Executive Officer for Space

June 26, 2015

NOT FOR PUBLICATION UNTIL RELEASED BY
SUBCOMMITTEE ON STRATEGIC FORCES
HOUSE ARMED SERVICES COMMITTEE
U.S. HOUSE OF REPRESENTATIVES

Chairman Rogers, Ranking Member Cooper, and distinguished Members of the Subcommittee, thank you for the opportunity to appear before you today to discuss how we deliver space capabilities to the nation's warfighters today -- and tomorrow. As Ms. McFarland and General Hyten have said, space capabilities are essential to the American way of life and to the Air Force mission. Thanks to the efforts of the men and women of the Space and Missile Systems Center, the Air Force, and our contractors and mission partners, we have multiplied the effectiveness of our forces in the land, sea, and air domains through worldwide precision navigation, protected strategic and tactical communications, and Intelligence-Surveillance-Reconnaissance capabilities provided from space.

One of the keys in providing all of that capability is space launch. If we cannot launch a satellite when we need to, we will not have those much needed space capabilities when we need them. As you know, we address the critical nature of launch through a policy of assured access to space, maintaining at least two reliable launch systems with independent technical baselines as a credible method for continued access to space, should one suffer a grounding event. Assured access to space makes sense, and it is mandated by Title 10, Section 2273 of the US Code, which requires "the availability of at least two space launch vehicles (or families of space launch vehicles) capable of delivering into space any payload designated by the Secretary of Defense or the Director of National Intelligence as a national security payload."

We purchase launch services on a commercial basis. Leveraging commercial space transportation services whenever possible is mandated by the Commercial Space Act (51 U.S.C. §50131). This is a good thing -- the market for space products and space launch continues to mature, and as in many other areas, our free market here in America is an important source of innovation and national economic strength. I applaud the success our partners at NASA have had in using public-private partnerships to reduce the cost of routine cargo deliveries to the International Space Station. Similarly, leveraging the free market through reintroducing competition for Evolved Expendable Launch Vehicle – EELV – class launches will help us reduce our costs and gain additional access to industry innovation.

The Air Force is Complying with the FY15 National Defense Authorization Act

These two concepts, assured access to space via reliable launch vehicles and competition, are the cornerstones of our national launch policy and are written into law. Section 1608 of the 2015 National Defense Authorization Act (NDAA) restricts the use of the RD-180 rocket engine. Just as decisions were made for industry to adopt the RD-180 in the 1990s, we are complying with law to reduce strategic reliance on foreign Rocket Propulsion Systems now. The Air Force is 100% committed to transitioning off of the RD-180 for national security space launch as quickly and prudently as possible.

Section 1604 of the 2015 NDAA requires that we develop a domestic next-generation rocket propulsion system suitable for national security use by 2019, that it be available for purchase by all domestic space launch providers, and that we examine the feasibility of public-private partnerships to do so. As we implement this law, we must continue to execute our two cornerstones, assured access to space and competition, to achieve the end state necessary to maintain our military effectiveness: at least two domestically-produced, commercially-viable launch providers that are also able to meet national security space requirements by the end of FY22.

Assured access to space requires space launch services and not just a rocket engine. The pending restriction on spending FY16 funds only for rocket propulsion system development will potentially delay the availability of those space launch services required to continue to assure access to space without reliance on foreign Rocket Propulsion Systems.

Procuring Launch Services is Necessary to Maintain Assured Access to Space

Our ability to maintain affordable assured access to space after 2018 is currently jeopardized. At the moment, two providers are capable of meeting some or all of our EELV launch requirements, using three families of launch vehicles. Last month, on behalf of the Air Force, I approved certification of SpaceX as a NSS launch-service provider. This milestone now means that we have more than one credible, certified launch service provider to support NSS missions. We also currently have the certified ULA Atlas and Delta rocket families. Unfortunately, according to ULA, the Delta is not cost-competitive with either the Atlas or the Falcon 9, and they have announced plans to retire it by 2018, except for the Heavy variant which primarily launches unique national security payloads. ULA plans to transition to the new Vulcan launch vehicle, which is also intended to serve the entire range of national security space launch requirements. After 2018, and until Vulcan is certified, ULA has said that it intends to offer only Atlas. Therefore we are pursuing a number of options to ensure at least two launch systems remain available at all times in case one suffers a grounding event.

Simply replacing the RD-180 with a new engine is not the answer. Rockets are built around engines. To accelerate a payload to orbital velocity, rocket engines must release and direct tremendous amounts of energy, while the rocket structure itself must be kept as light as possible. Each RD-180 produces more than four times as much power as all four of a Boeing 747's engines combined, while an empty Atlas V only weighs about one-and-a-half times as much as that same empty 747. Vibrations from the rocket engine ripple through the launch vehicle as it travels, potentially damaging the payload, or the vehicle itself. To prevent that, every rocket is heavily influenced by the design of its engine. To do otherwise produces outcomes that are suboptimal in terms of performance, safety, cost, and development timelines. You cannot simply drop in a replacement rocket engine without extensively re-engineering the entire launch system.

To be clear, even a drop-in replacement which closely matches the RD-180 physical interfaces and performance would require modifications to the launch vehicle structures, the fuel and oxidizer feedlines, and the heat shields to accommodate even minor differences in performance. The thrust vector control and throttling of the RD-180 engine is a critical characteristic of the Atlas V. The new engine's thrust vectoring and throttling will require changes to the electronic control systems and significant engineering analysis to develop new flight profiles to launch the various satellites. Finally, a small difference in the performance of the replacement engine may have significant impact in the ability of the launch system to lift payloads to orbit.

A byproduct of this is that a rocket engine specifically engineered to replace the RD-180 on the Atlas, would most likely be usable only for ULA's Atlas, and not by another launch service provider without significant modifications to the engine and the launch vehicle. We also do not believe this would meet the intent of open competition. Additionally, from our market research, we found that if the Air Force procured an engine not designed for a specific launch vehicle, commercial providers would be unlikely to build a rocket around it without the Government also funding the redesign on the launch vehicle. So, in my opinion, an engine alone, even if made available to all launch service providers, would not solve the problem of maintaining assured access to space. In addition, this approach would limit competition at the launch vehicle level, where we need it most.

So, the Air Force is pursuing a strategy of shared investment with industry using public-private partnerships, which is consistent with the intent of the FY15 NDAA, at the launch service level, which includes rocket propulsion system development. Partnering with industry ensures that they share some of the cost burden, offers the best chance of solving technical challenges to meet schedule goals, and provides the opportunity to harness industry's creative ideas in ways to achieve propulsion and launch system performance requirements. Additionally, it will improve assured access by using commercial providers to develop domestic, commercially-viable launch systems, including the accompanying rocket propulsion systems, be they liquid fueled engines or solid rocket motors.

The 4-Step Plan Reduces Risks to Assured Access While Transitioning off RD-180

We are moving fast on this. We are developing an acquisition strategy to reach this end state as quickly as possible. Since the Mitchell Report was released last summer, we have conducted extensive market research, including an RFI to industry in August 2014 and a formal follow-up in February 2015; an independent review led by retired Air Force General Tom Moorman in February 2015; and consultations with NASA about the lessons learned from their shared investments in Commercial Orbital Transportation Services, Commercial Cargo, and Commercial Crew Transportation. The Air Force has gained tremendous insight into, and respect for, what NASA has accomplished with industry in the past ten years, and we plan to leverage its successful strategies and processes where appropriate.

In our research, we assess that industry timelines predicting complete rocket propulsion systems by 2019 are aggressive. History has consistently shown that developing, testing, and maturing an engine takes 6 to 7 years with another year or two beyond that to be able to integrate into the launch vehicle. Testing, in particular, is essential to successful engine development, and it takes time.

To minimize that risk while meeting our overarching goal of competitive assured access to space with domestic engines by FY22, we have developed a four-step plan to use a launch service approach to eliminate strategic reliance on foreign Rocket Propulsion Systems. The end goal is two or more domestic, commercially viable launch providers that also meet the more stressing national security space requirements.

All four of these steps take place within what we call Phase 2 of our EELV program strategy. Phase 1 of the overall strategy was composed of entering into a block buy with ULA, while certifying New Entrants to compete for launches. The purpose of this phase was to stabilize the industrial base to provide significant cost savings and to initiate competition with emerging EELV class launch providers. Phase 2 started at the beginning of FY15, and is a time of transition for the EELV program which must be managed very carefully to control costs while maintaining space capabilities.

The first step of the Phase 2 four-step plan is technical maturation and risk reduction activities for the highest-risk aspects of developing a rocket propulsion system. We have heard from industry that there are areas where the underlying science and technology needs to be advanced, such as modeling combustion stability in high-performance engines, improving the level of understanding of oxygen-rich staged combustion technologies here in the United States, developing additive manufacturing processes for engine production, and even in developing advanced solid motors. In the Fall and Winter, we initiated a large scale combustion stability test leveraging NASA's and the Air Force Research Labs' competitively awarded contracts and the test stands at NASA's Stennis Space Center. In late May, we awarded a contract to academia to develop much needed combustion stability tools. On June 2nd, we released a Broad Area Announcement for investments that will advance the state of art across the entire domestic rocket propulsion industry and we are currently evaluating the initial responses.

The second step is shared investment in rocket propulsion systems. On June 2nd, we also released a Request for Proposals, soliciting partners to enter into Other Transaction Authority (OTA) agreements to develop rocket propulsion systems, as authorized by the NDAA. We contemplate awarding a portfolio of up to four agreements worth a total of about $160 million. Because we are encouraging commercial systems, they require a non-governmental investment to cover at least a third of the costs going forward. The intent of this step is to mature rocket propulsion systems, in partnership with launch vehicle providers, through technical and programmatic reviews and demonstrations, including tests at the component, subscale, or engine level. We do not plan on waiting to make all the awards at once. We will make rolling awards from September through December.

The third step is to transition our shared investment in propulsion systems to launch systems. We plan to release this RFP late this year, with awards in the spring of 2016, using FY16 funding. Like the OTAs used to initiate rocket propulsion development, these will be competitively awarded to multiple vendors using a shared investment approach. Additionally, launch system development will include technical and programmatic reviews and demonstrations, including component, subscale, or full-scale testing. We intend for the activities under this award to occur in parallel with certification activities for the launch systems to minimize the time between the end of development and the use of the system for national security space launch.

The fourth step is to actually acquire launch services using currently certified systems, while on-ramping new launch systems as they complete certification. These awards will be made using Federal Acquisition Regulation-compliant contracts for launch services. We plan to begin these procurements in FY18 and run through FY22, for launches occurring from FY20 to FY24. Both in response to Congressional direction, and because it better aligns with our goal of procuring commercially viable launch services, we anticipate to award these procurements on a fixed-price basis, without additional launch capability contracts.

By following this four step plan, we intend for a smooth transition from this step to the fully competitive environment of Phase 3. The shared investment with our industry partners in the second and third steps will define technical solutions and schedules for achieving domestically manufactured rocket propulsion systems. Based on their progress, the Government and Industry will have data to confirm whether the business case closes for pursuing these partnerships before entering step four.

Conclusion

Mr. Chairman, Mr. Ranking Member, Members of the Subcommittee, rocket science is hard. The history of rocket development has resulted in amazing accomplishments and catastrophic failures, as seen both here and abroad within the past year, with sometimes tragic results. This highlights the success of the Delta IV and Atlas V launch systems, with a combined 83 launches without a catastrophic failure resulting in the loss of a primary payload, and the Falcon 9, which is now up to 18 launches.

As we move forward, we need to maintain our laser-focus on mission success, to protect the safety of the American people and to deliver battlefield capability to our warfighters. We believe the best way to do that is through partnering with launch service providers to share the burden of development and reduce risks. If we do that, we will be on a path to transitioning off of the RD-180 and having at least two domestically-produced, commercially-viable launch providers that are certified to meet national security space requirements by the end of FY22. Thank you for your support in helping us get there.

Lieutenant General Samuel A. Greaves
Commander, Space and Missile Systems Center

Lt. Gen. Samuel A. Greaves is the Commander, Space and Missile Systems Center, Air Force Space Command, Los Angeles Air Force Base, California.

He is responsible for more than 5,000 employees nationwide and an annual budget of $6 billion. As the Air Force Program Executive Officer for Space, General Greaves manages the research, design, development, acquisition, and sustainment of satellites and the associated command and control systems. His extensive portfolio includes military satellite communication, missile warning, navigation and timing, space-based weather, space launch and test ranges, certification for launch, space superiority, responsive space and other emerging evolutionary space programs.

General Greaves was commissioned in 1982 through the Reserve Officer Training Corps program after he graduated from Cornell University. He has held a variety of assignments in operational, acquisition and staff units, including assignments at Headquarters Air Combat Command; the National Reconnaissance Office; and on the Air Staff within the Directorate of Operational Requirements and the Air Force Colonel Matters Office. He commanded the 45th Launch Group at Patrick AFB, Florida, the Launch and Range Systems Wing and Military Satellite Communications Systems Wing at Los Angeles AFB, California. The general also served as Vice Commander, Space and Missile Systems Center, Los Angeles AFB, California, and then as Director, Strategic Plans, Programs and Analyses, Headquarters Air Force Space Command, Peterson AFB, Colorado. Prior to his current assignment, he was the Deputy Director, Missile Defense Agency, Redstone Arsenal, Alabama.

He has operational launch crew experience in the space shuttle, Titan, Atlas and Delta space-launch systems. He wears the Command Space Badge.

EDUCATION
1982 Bachelor of Science degree in electrical engineering, Cornell University, Ithaca, N.Y.
1984 Master of Science degree in computer science, West Coast University, Los Angeles, Calif.
1986 Squadron Officer School, Maxwell AFB, Ala.
1997 Distinguished graduate, Air Command and Staff College, Maxwell AFB, Ala.
1997 Undergraduate Space and Missile Training, Staff Course, Vandenberg AFB, Calif.
1999 Air War College, by correspondence, with distinction
2001 Master's degree in strategic studies, Air War College, Maxwell AFB, Ala.
2003 Program Managers Course, Defense Systems Management College, Fort Belvoir, Va.
2008 Executive Program Managers Course, Defense Systems Management College, Fort Belvoir, Va.
2010 NSP Executive Course, George Washington University, Washington, D.C.
2010 Systems Acquisition Management Course, Fort Belvoir, Va.
2011 Requirements Executive Overview Workshop, Peterson AFB, Colo.

ASSIGNMENTS
1. June 1982 - December 1984, space shuttle avionics engineer, Vandenberg AFB, Calif.
2. December 1984 - June 1986, avionics engineer, Space Shuttle Main Engines, Kennedy Space Center, Fla.
3. June 1986 - October 1987, Chief, Titan Inter-Range Operations, 6595th Aerospace Test Group, Vandenberg AFB, Calif.
4. October 1987 - March 1990, Titan Space Launch Systems Manager, 6595th Aerospace Test Group, Vandenberg AFB, Calif.
5. March 1990 - January 1992, Chief, Spacecraft Test and Launch Operations, SP-11 Program Office,

Secretary of the Air Force Office of Special Projects, Los Angeles, Calif.
6. January 1992 - March 1994, Chief, Satellite Engineering, SP-11 Program Office, Secretary of the Air Force Office of Special Projects, Los Angeles, Calif.
7. March 1994 - August 1995, executive officer to the Director, Secretary of the Air Force Office of Special Projects, Los Angeles, Calif.
8. August 1995 - August 1996, National Space Systems Applications Manager, Directorate of Requirements, Headquarters Air Combat Command, Langley AFB, Va.
9. August 1996 - August 1997, student, Air Command and Staff College, Maxwell AFB, Ala.
10. August 1997 - June 1998, Chief, Surveillance and Reconnaissance Requirements, Space and Reconnaissance Division, Directorate of Operational Requirements, Deputy Chief of Staff for Air and Space Operations, Headquarters U.S. Air Force, Washington, D.C.
11. June 1998 - June 1999, executive officer to the Director of Operational Requirements, Deputy Chief of Staff for Air and Space Operations, Headquarters U.S. Air Force, Washington, D.C.
12. June 1999 - July 2000, Deputy Chief, Assignments Division, and Chief, Space, Missile, Acquisition and Technical Assignments, Air Force Colonel Matters Office, Headquarters U.S. Air Force, Washington, D.C.
13. July 2000 - June 2001, student, Air War College, Maxwell AFB, Ala.
14. June 2001 - July 2002, Commander, Air Force Communications Support Facility, White Sands Missile Range, N.M.
15. August 2002 - June 2004, Materiel Group Director, Air Force Satellite Control Network, Space and Missile Systems Center, Los Angeles AFB, Calif.
16. June 2004 - August 2006, Commander, 45th Launch Group, Cape Canaveral Air Force Station, Fla.
17. August 2006 - June 2008, Commander, Launch and Range Systems Wing, Los Angeles AFB, Calif.
18. June 2008 - August 2009, Commander, Military Satellite Communications Systems Wing, Los Angeles AFB, Calif.
19. August 2009 - February 2011, Vice Commander, Space and Missile Systems Center, Los Angeles AFB, Calif.
20. February 2011 - August 2012, Director, Strategic Plans, Programs and Analyses, Headquarters Air Force Space Command, Peterson AFB, Colo.
21. August 2012 – June 2014, Deputy Director, Missile Defense Agency, Redstone Arsenal, Ala.
22. June 2014 - present, Commander, Space and Missile Systems Center and Program Executive Officer for Space, Los Angeles AFB, Calif.

SUMMARY OF JOINT ASSIGNMENTS
1. August 2012 - June 2014, Deputy Director, Missile Defense Agency, Redstone Arsenal, Ala., as a major general

OPERATIONAL INFORMATION
Space Shuttle Missions: 51-C, 51-D, 51-B, 51-G, 51-F, 51-I, 51-J, 61-A, 61-B, 61-C, 51-L
Titan: 34B-66, 34D-15, II-G1, 34D-14, II-G2
Titan IV: B-30
Delta II: NASA MESSENGER, Swift, Deep Impact, GPS IIR-13/GPS IIR-14(M), MiTEx, GPS IIR-15(M), GPS IIR-16 (M), GPS IIR-17 (M), GPS IIR-18 (M), GPS IIR-19(M)
Delta IV: Air Force Heavy Demo, GOES-N, DMSP-17, DSP-23
Atlas II/III: AC-167, NROL-1, AC-206
Atlas V: AMC-16, INMARSAT-IV, NASA MARS Reconnaissance Orbiter, Pluto New Horizons, ASTRA, WGS-1, NRO L-24, NRO L-28, WGS-2

MAJOR AWARDS AND DECORATIONS
Distinguished Service Medal
Legion of Merit with oak leaf cluster
Defense Meritorious Service Medal with two oak leaf clusters
Meritorious Service Medal with two oak leaf clusters

Air Force Commendation Medal with two oak leaf clusters
Air Force Achievement Medal

OTHER ACHIEVEMENTS
2008 Lt Gen John W. O'Neill Outstanding System Program Director Award

PROFESSIONAL CERTIFICATIONS
1994 Program Management, Level III, Acquisition Professional Development Program
1994 Research and Development, Level III, APDP
1994 Test and Engineering, Level I, APDP

EFFECTIVE DATES OF PROMOTION
Second Lieutenant June 2, 1982
First Lieutenant June 2, 1984
Captain June 2, 1986
Major July 1, 1994
Lieutenant Colonel Feb. 1, 1999
Colonel Aug. 1, 2003
Brigadier General Dec. 9, 2008
Major General July 13, 2012
Lieutenant General June 19, 2014

(Current as of June 2014)

Statement of

Michael D. Griffin

before the

U.S. House of Representatives
Committee on Armed Services
Subcommittee on Strategic Forces

Hearing on

Assuring National Security Space: Investing in American Industry to End Reliance on Russian Rocket Engines

Rayburn House Office Building
Room 2212

26 June 2015

Chairman Rogers, Ranking Member Cooper, and distinguished members of the Committee, I am honored to be asked to appear before this subcommittee to testify on the matter before us today. Before beginning any substantive discussion, I will note that I am here as an independent witness and as a private individual. I have received no consideration of any kind in connection with the topic of today's hearing. I am here on personal leave and at personal expense, and am not representing any company, agency, or committee on which I have served or presently serve.

We are here today because of problems affecting our national security space launch architecture. Because of Russian actions in Ukraine and U.S. legislative response to those actions (Section 1608 of the FY15 National Defense Authorization Act, PL 113-291), the U.S. has determined to end the dependence of our national security space launch systems on the Russian RD-180 rocket engine, the largest and best performing oxygen/kerosene engine in the world. However, even had the Congress not taken such action, future access to this engine would be in doubt. Numerous thinly-veiled Russian threats have clearly shown the risk of continued dependence by the United States on Russia for such a strategic good.

But the RD-180 has been used for two decades on various versions of the Atlas launch vehicle, and without that engine or a functionally equivalent replacement, today's Atlas 5 launch vehicle will be grounded. The significance of this can be understood simply by noting that, today, about two-thirds of our national security payloads go to space on the Atlas 5. Thus, while I completely agree that we should not be dependent upon a foreign power, much less an adversary, for any element of our national space launch capability, I believe that the legislative action which has been taken in this regard is a bit too abrupt. It might be that we could wean ourselves of this dependence a bit more gently.

The decision to allow the import of the RD-180 and its use on the Atlas launcher was made some twenty years ago, in the mid-nineties, for valid geopolitical and economic reasons. It must be said that, even then, the geopolitical and industrial base consequences of a decision to allow such a strategic dependence upon a foreign power, even as we attempted to build closer ties to that power, were well understood. To mitigate those consequences, it was agreed by all parties that the U.S. would develop the capability for domestic co-production of the RD-180. Regrettably, and for a variety of reasons mostly involving perceived budget priorities, these co-production agreements were never implemented. Now our legal right to do so is about to expire, and it is quite simply too late. This is not a nuanced matter; either a functional American equivalent for the RD-180 is developed, or the Atlas is grounded.

If the Atlas is grounded, what then? The options are both limited and unpalatable. U.S. policy and law require two independent systems for national security space launch capability. This requirement is met, but only partially so, with the Delta 4 family of launch vehicles. Many critical payloads are not immediately interchangeable between launch vehicles, and would require some amount of rework, at considerable cost in time and money, to shift from Atlas to Delta. Moreover, the Delta is in general more expensive than the equivalent Atlas, which in part accounts for the numerical imbalance in favor of Atlas launches. Finally, Delta production limitations are such that without a massive increase in manufacturing and launch infrastructure, very limited surge capacity is available. The net effect of shifting national security space systems from Atlas to Delta will be several years of delay for the average payload, and many billions of dollars of increased cost.

Some have said that the best path forward is to discard decades of government investment in and experience with the Atlas, and develop a whole new system. Now, I must say that in my opinion the U.S. national security launch architecture could indeed benefit from a top-down review and, quite possibly, new policies and systems ranging from ground and flight infrastructure, to maintenance of the required industrial base, to new acquisition approaches. But the kind of broad-based re-thinking that would ultimately result in the creation of one or more new launch systems will require a decade or more to realize, and neither can nor should be done in haste. This does nothing to solve today's problems. And even if it did, it is irrational to suppose that an entirely new vehicle can be obtained more quickly or at less cost than a new engine alone.

Others would have us believe that the U.S. government can merely purchase launch services from among multiple competitors, as if one were selecting a particular airline for a desired trip based on airfare and schedule. Purveyors of this "launch as a service" view would have us believe that if we have an engine supply problem, the U.S. government should stay on the sidelines while the market solves the problem.

If we are to preserve American access to space while ending our dependence on Russia in the quickest and least costly manner possible, we must reject this view. The fact is that the domestic launch market is essentially a monopsony. Almost all demand is from the U.S. government, while the supply side consists of three providers, each of which offers somewhat different capability. None of these launch providers could remain in business without the pillar of U.S. government demand.

Thus, the U.S. national security launch architecture is a strategic capability having far more in common with the other strategic assets such as fighters, bombers, aircraft carriers and submarines than it does with airlines and cruise ships. The vagaries of the market cannot be allowed to determine whether or not critical payloads make it to space in a timely fashion. Accordingly, the U.S. government must be prepared to ensure that the supply chain required to maintain this critical asset remains intact. That supply chain is currently quite fragile; while we have been supporting the Russian rocket engine industrial base, our own has withered.

To conclude: we have an engine problem, not a rocket problem. I believe we should solve it by building a government funded, government owned American equivalent to the RD-180 as quickly as we can possibly do so. We should not allow the many obfuscating issues which have been raised in connection with this problem to cloud our view of what must be done to solve it.

Michael D. Griffin

Michael Griffin is the King-McDonald Eminent Scholar and Professor of Mechanical and Aerospace Engineering, and the Director of the Center for System Studies at The University of Alabama in Huntsville. From 2005-09 he was the Administrator of NASA. Prior to rejoining NASA he was Space Department Head at the Johns Hopkins University Applied Physics Laboratory. He has also held numerous executive positions with industry, including President and Chief Operating Officer of In-Q-Tel, Chief Executive Officer of Magellan Systems, General Manager of Orbital Science Corporation's Space Systems Group, and Executive Vice President and Chief Technical Officer at Orbital.

Mike's earlier career includes government service as both Chief Engineer and Associate Administrator for Exploration at NASA, and as the Deputy for Technology at the Strategic Defense Initiative Organization. Prior to joining SDIO in an executive capacity, he played a key role in conceiving and directing several "first of a kind" space tests in support of strategic defense research, development, and flight testing. These included the first space-to-space intercept of a ballistic missile in powered flight, the first broad-spectrum spaceborne reconnaissance of targets and decoys in midcourse flight, and the first space-to- ground reconnaissance of ballistic missiles during the boost phase. He also played a leading role in other space missions in earlier work at the JHU Applied Physics Laboratory, NASA's Jet Propulsion Laboratory, and the Computer Science Corporation.

Mike previously taught for thirteen years as an adjunct professor at the University of Maryland, the Johns Hopkins University, and George Washington University, offering courses in spacecraft design, applied mathematics, guidance and navigation, compressible flow, computational fluid dynamics, spacecraft attitude control, astrodynamics, and introductory aerospace engineering. He is a Registered Professional Engineer in Maryland and California, and is the lead author of over two dozen technical papers and the textbook Space Vehicle Design.

Griffin is member of the National Academy of Engineering and the International Academy of Astronautics, an Honorary Fellow of the American Institute of Aeronautics and Astronautics, a Fellow of the American Astronautical Society, and a Senior Member of the Institute of Electrical and Electronic Engineers. He is the recipient of numerous honors and awards, including the NASA Exceptional Achievement Medal, the AIAA Space Systems Medal and Goddard Astronautics Award, the National Space Club's Goddard Trophy, the Rotary National Award for Space Achievement, and the Department of Defense Distinguished Public Service Medal, the highest award which can be conferred on a non-government employee.

Mike obtained his B.A. in Physics from the Johns Hopkins University, which he attended as the winner of a Maryland Senatorial Scholarship. He holds Master's degrees in Aerospace Science from Catholic University, Electrical Engineering from the University of Southern California, Applied Physics from Johns Hopkins, Civil Engineering from George Washington University, and Business Administration from Loyola College of Maryland. He received his Ph.D. in Aerospace Engineering from the University of Maryland, and has been recognized with honorary doctoral degrees from Florida Southern College and the University of Notre Dame.

Mike was born in 1949 in Aberdeen, Maryland. His hobbies include golf, flying, amateur radio, skiing, and scuba diving. He is a Certified Flight Instructor with instrument and multiengine ratings, and holds an Extra Class radio amateur license.

DISCLOSURE FORM FOR WITNESSES
COMMITTEE ON ARMED SERVICES
U.S. HOUSE OF REPRESENTATIVES

INSTRUCTION TO WITNESSES: Rule 11, clause 2(g)(5), of the Rules of the U.S. House of Representatives for the 114th Congress requires nongovernmental witnesses appearing before House committees to include in their written statements a curriculum vitae and a disclosure of the amount and source of any federal contracts or grants (including subcontracts and subgrants), or contracts or payments originating with a foreign government, received during the current and two previous calendar years either by the witness or by an entity represented by the witness and related to the subject matter of the hearing. This form is intended to assist witnesses appearing before the House Committee on Armed Services in complying with the House rule. Please note that a copy of these statements, with appropriate redactions to protect the witness's personal privacy (including home address and phone number) will be made publicly available in electronic form not later than one day after the witness's appearance before the committee. Witnesses may list additional grants, contracts, or payments on additional sheets, if necessary.

Witness name: Michael D. Griffin

Capacity in which appearing: (check one)

◉ Individual

○ Representative

If appearing in a representative capacity, name of the company, association or other entity being represented: ______

Federal Contract or Grant Information: If you or the entity you represent before the Committee on Armed Services has contracts (including subcontracts) or grants (including subgrants) with the federal government, please provide the following information:

2015

Federal grant/ contract	Federal agency	Dollar value	Subject of contract or grant

2014

Federal grant/ contract	Federal agency	Dollar value	Subject of contract or grant
1026A	DoD USAF-RL/RV	$49,279	RD-180 Risk Mitigation Study

2013

Federal grant/ contract	Federal agency	Dollar value	Subject of contract or grant

Foreign Government Contract or Payment Information: If you or the entity you represent before the Committee on Armed Services has contracts or payments originating from a foreign government, please provide the following information:

2015

Foreign contract/ payment	Foreign government	Dollar value	Subject of contract or payment

2014

Foreign contract/ payment	Foreign government	Dollar value	Subject of contract or payment

2013

Foreign contract/ payment	Foreign government	Dollar value	Subject of contract or payment

DOCUMENTS SUBMITTED FOR THE RECORD

JUNE 26, 2015

Rocket propulsion system development program (sec. 1604)

The House bill contained a provision (sec. 1604) that would direct the Secretary of Defense to develop a next-generation liquid rocket engine authorized at $220.0 million for fiscal year 2015. In carrying out the program, the Secretary would be required to coordinate with the Administrator of the National Aeronautics and Space Administration, to the extent practicable. The provision also contained a sense of Congress that the engine be made in the United States, meet the requirements of the national security space community, developed not later than 2019 using full and open competition, and available for purchase by all space launch providers of the United States.

The Senate committee-reported bill contained a similar provision (sec. 1629) that would require the Secretary of Defense to develop a program plan for the production of a liquid rocket engine to support national security launch missions by no later than 2019.

The agreement includes the House provision with an amendment that would direct the Secretary of Defense to develop a rocket propulsion system that is made in the United States, is developed no later than 2019 using full and open competition, meets the requirements of the national security space community, and is available for purchase by all space launch providers of the United States.

We note that this provision is not an authorization of funds for the development of a new launch vehicle. This provision is for the development of a rocket propulsion system to replace non-allied space launch engines by 2019.

The Secretary should coordinate with the Administrator of the National Aeronautics and Space Administration, to the extent practicable, to ensure that the rocket propulsion system developed under subsection meets objectives that are common to both the national security space community and the civil space program of the United States.

Liquid Rocket Engine—Multi Program Applicability

Examples of Rocket Engines Used on Multiple Vehicles/Stages:

Engine	Manufacturer	Propellants	Used On (Vehicles)	Used On Stages
Merlin	SpaceX	LOX/RP–1	Falcon 1, Falcon 9	Falcon 1–1, Falcon 9–1, Falcon 9–2
RS–27	Rocketdyne	LOX/RP–1	Delta II, Delta III	Delta Thor ELT, Delta Thor RS27, Delta Thor XLT, Delta 3–1, Delta Thor XLT–C
H–1	Rocketdyne	LOX/RP–1	Saturn 1, Saturn 1B	Saturn I–1, Saturn IB–1, Saturn S–IB–A
RD–180	Glushko	LOX/RP–1	Atlas IIIA, Atlas IIIB, Atlas V	Atlas CCB, Atlas IIIA
MA–5/LR89–7	Rocketdyne	LOX/RP–1	Atlas Centaur LV–3C, Atlas Agena D, Atlas Centaur D, Atlas H, Atlas Centaur G, Atlas I	Atlas MA–5
LR105–5	Rocketdyne	LOX/RP–1	Atlas Centaur LV–3C, Atlas E/F, Atlas Agena B	Atlas Agena SLV–3, Atlas Centaur SLV–3C/D, Atlas E/F
HM–7B	SEP, Ottobrunn	LOX/LH2	Ariane 2/3, Ariane 4	Ariane H10, H10–3, Ariane 5 ESC A, Ariane H10plus
RL–10	Rocketdyne	LOX/LH2	Atlas I, Atlas II, Titan III, Titan IV, Delta III, Delta IV, Saturn I, Saturn IB, DC–X	Saturn IV, Centaur B/C/D/E/G, Centaur I/II/IIA/IIIA/IIIB, Centaur G Prime, Centaur G STS, Centaur V 1/2, DC–X, Delta 4H–2, Delta 4–2, Delta 3–2
AR2–3	Rocketdyne	H2O2/Kerosene	NF–104, X–37	NF–104, X–37
AJ10–118	Aerojet	RFNA/UDMH	Delta, Vanguard	Delta A/D/E/F/G/J/K
LR91–11	Aerojet	N2O4/Aerozine-50	Titan 3, Titan 4	Titan 4–2, Titan 3A–2, Titan 3B–2
NK–33–1/AJ–26	Kuznetsov/Aerojet	LOX/RP–1	Antares, Soyuz 2.1v, N–1	N1–2, Antares 1, Soyuz 2.1v-1
J–2	Rocketdyne	LOX/LH2	Saturn IB, Saturn V	Saturn IVB (S–IB), Saturn IVB (S–V), Saturn II
SSME	Aerojet Rocketdyne	LOX/LH2	Shuttle, SLS	STS Orbiter, SLS Core stage

Examples of Launch Vehicles Where Engines Were Replaced:

Antares	Replacing AJ–26/NK–33 (LOX/RP) with RD–181—ongoing
Atlas IIAS to Atlas III	Replaced MA–5A (LOX/RP) with RD–180
Space Shuttle	Many major SSME upgrades (LOX/LH2) (including new turbopumps, powerhead ducting, main combustion chamber) over 40 years on Shuttle
Falcon	Merlin 1 to Merlin 1D (20% thrust upgrade), booster and vacuum versions
Titan I to II	LR–87–3 (LOX/RP) to LR–87–5 (nit tetroxide/hydrazine/UDMH)
Saturn SIV to SIVB	RL–10 to J–2 (LOX/LH2)
Centaur C–E to IIA to IIIA/B Series	RL–10A–1 (47:1 exp ratio) to RL–10A–3 (57:1 exp ratio) to RL–10A4–1/2 (extentable 84:1 exp ratio) (LOX/LH2)

WITNESS RESPONSES TO QUESTIONS ASKED DURING THE HEARING

JUNE 26, 2015

RESPONSES TO QUESTIONS SUBMITTED BY MR. ROGERS

Ms. VAN KLEECK. It is Aerojet Rocketdyne's position that major modifications to the Atlas V launch vehicle are not required to integrate the AR1 main propulsion system as a replacement for the RD–180. Aerojet Rocketdyne engineers have been working directly with ULA engineers under a cooperative agreement to ensure that AR1 will interface with the existing Atlas vehicle and launch pad infrastructure. For example, Aerojet Rocketdyne has taken specific actions to ensure the length of the AR1 engine does not interfere with the mobile launch platform. AR1 propellant interfaces meet the RD–180's, ensuring major re-routing of vehicle feed lines is not required. Some modification to avionics, ancillary feed systems, thrust structure, etc. will be required but are considered minor impacts. If ULA chooses to take advantage of the AR1's increased performance over the RD–180 by increasing the vehicle's propellant load, that would require greater changes to the launch vehicle and pad; however, it is Aerojet Rocketdyne position that those changes are not required to address the immediate concern of maintaining the viability of Atlas and could be reserved for future upgrades. In addition, it is Aerojet Rocketdyne's position that none of these upgrades represent the level of impact to all aspects of ULA's launch infrastructure that will be required by a the proposed new methane/liquefied natural gas (LNG) fueled "Vulcan" launch vehicle. [See page 20.]

Dr. GRIFFIN. My list of re-engined stages and engines which have been used on more than one launch platform is attached. [See page 42.]

[The list referred to can be found in the Appendix on page 164.]

RESPONSE TO QUESTION SUBMITTED BY MR. LAMBORN

Mr. THORNBURG. The Falcon 9 Launch System was certified on May 27, 2015. As General Hyten, General Greaves, Secretary McFarland, and Dr. Griffin noted in response to your line of questions, the Air Force has a standard procedure in place to validate upgrades to launch systems in the EELV Program. These procedures have been used for both the Atlas V and Delta IV systems for numerous upgrades, including to the RL10 upper-stage engine and the RS–68A first-stage engine, among other upgrades for the incumbent provider's rockets.

In their testimony, Gen Hyten and Gen Greaves, explained this process (emphasis added):

"HYTEN: And the other point I will say, sir, is that part of the transition phase of that is moving to the full thrust engines on their Merlin capability. **Now that's a very similar process to what we went through on the Delta vehicle when we went from an RS–68 to the RS–68A.** They actually work closely with us as they go through that. **That's part of the normal process, that we work with both Atlas and Deltas over the years. We've done that on the upper stage as well. Once we go through and certify the system, it's basically a baseline capability,** and then as industry learns and develops new capabilities, they have to come back to us and demonstrate their changes that go through. And the lucky part is General Greaves is actually the certifier. So he can talk about all the details of that. So I will pass it to General Greaves.

GREAVES: Well, Congressman, as General Hyten said, the Air Force has designated my position as the certification official for new entrants. And as part of that in assessing SpaceX's capability, we're working with them very closely. In fact, I co-chair meetings every two weeks with Gwynne Shotwell, Elon Musk level, to assess the current status of what they have proposed, any changes that they are envisioning or have realized into their system to ensure it becomes certified in time. **So in the end we are well aware of proposed changes to the Falcon 9 1.1 system as part of the upgrade that was discussed in the other panel. We are daily, our teams are organic government team, our FRDC team, we are working with SpaceX to fully understand what it will what it will take to accept those changes, whatever they may be, as a certified system. This is no different, sir, than we have done with ULA in the past.** In fact, last December, when we flew the RL10C, which is an upgraded second stage engine, we went through a significant effort with ULA ahead of time to understand the changes of that system, what it of that engine, what it would do to the system and then certify it for flight, which is which we did last December and it flew very successfully for the first time. So, today as we speak, SpaceX has provided what changes they envision for the upgraded Falcon 9. We are daily in an intense effort with them to understand and hopefully certify that system.

LAMBORN: And you mentioned test flights in the case of ULA, will test flights be part of the protocol with SpaceX?

GREAVES: As a as a basis, yes, sir, but **I will use the RL10C as an example. That engine was qualified as part of ULA's design and delivery process. And we flew it for the first time with an operational mission,** it was a classified mission, back in December. So it depends on the level, degree, amount, impact of the changes that we're looking at to determine whether or not it would require a reflight or test flight. **It is no different, sir, than what we've done historically with our launch providers.**

LAMBORN: And, Dr. Griffin, would you care to comment?

GRIFFIN: **I would agree with General Greaves with regard to certification of new capability.** In fact, I would say the idea that we fly a large number of repeated copies of rockets is something that may look true from the outside but, truthfully, it's rare to go very long in a string without upgrading or changing something about the rocket. So you are in this continual process of evolution and, certainly, certainly we don't do a non-value-added test flight, a whole separate test flight with no payload, merely because we go from an RL10B to an RL10C. You just wouldn't want to spend that kind of money. On the other hand, when you're fielding an entirely new rocket, you will do a couple of test flights before typically before you put a valuable payload on it. So there's an informed engineering and program management judgment that has to be applied to determine when you're willing to risk an upgrade without a test flight and when you need when you need a test flight because the upgrade is just so big that you don't want to risk the payload." [See page 30.]

RESPONSE TO QUESTION SUBMITTED BY MR. COFFMAN

Mr. THORNBURG. SpaceX refers you to our response to Question #15 from Mr. Coffman [on page 176]. [See page 17.]

QUESTIONS SUBMITTED BY MEMBERS POST HEARING

JUNE 26, 2015

QUESTIONS SUBMITTED BY MR. ROGERS

Mr. ROGERS. When there is a failure of a launch system, which is the same system to be used national security space missions, should the Department conduct an independent failure review board? Why or why not? What is the historical precedent?

Secretary MCFARLAND. If a launch system that carries, or intends to carry, a National Security Space (NSS) payload has a flight failure, as has recently occurred with the Space X Falcon 9, the Department expects to be granted insight into the investigation and its findings. This expectation remains true even if the launch failure did not involve an NSS payload.

Failure investigations for NSS missions are typically handled by the Air Force under Air Force Safety and Accident Board regulations. For additional information on this process the Air Force can provide you with details of historical precedents and current Failure Review Board practices. This effort is performed under the direction of the Air Force Space Command Commander and the Air Force Space and Missile System Center Commander.

Mr. ROGERS. Considering SpaceX's recent failure with a Falcon 9, are you planning to revisit the certification decision? Why or why not? If there is no root cause identified and final plan to address the problem before the upcoming GPS launch competition, what is your plan?

Secretary MCFARLAND. Air Force Space Command is charged with determining the certification status of any launch system/launch provider seeking to provide launch services for National Security Space payloads. The Space and Missile Systems Center Commander (SMC/CC) is the designated certification official and makes all certification decisions.

If a root cause for the Space X Falcon 9 v1.1 flight failure is not identified prior to the award of the GPSIII–2 launch service, the certifying official will make a risk-based decision on the offered launch systems certification status. The evaluation criterion for the GPS III–2 mission, which has been released for industry review, requires that the offered launch system must be certified. Unless the launch system offered to the government is not certified, the contractor proposals will be evaluated in accordance with the published criteria.

Mr. ROGERS. When there is a failure of a launch system, which is the same system to be used national security space missions, should the Department conduct an independent failure review board? Why or why not? What is the historical precedent?

General HYTEN and General GREAVES. (1) The Air Force conducts parallel, independent investigations or reviews of significant launch anomalies and launch failures of launch systems used for NSS missions, regardless of the nature of the mission.

(2) NSS missions are subject to the USAF mission assurance process, resulting in a certification of spaceflight worthiness. Therefore, the cause and corrective action of any failure of a launch system used for NSS launches needs to be understood so that any residual risks can be folded into the spaceflight worthiness assessment for future NSS missions. Furthermore, in the event of the failure of a NSS mission, an AFSPC-chartered Accident Investigation Board (AIB) or Independent Review Team would need to ascertain whether the NSS mission assurance process adequately addressed any elevated risk areas. The USAF would conduct an independent failure review for any NSS launch failure.

For non-NSS missions (such as the SpaceX Falcon 9–20 CRS–7 mission), other agencies such as the FAA would have the responsibility for mishap reviews; but AFSPC (to include SMC) have official representation on those review teams and access to all data. AFSPC or the Department could choose to begin an independent review at any time if needed to support a future NSS mission.

The Air Force mission assurance process includes a post flight analysis for all launches whether successful or not. The results of these analyses are incorporated into the spaceflight worthiness determination for future launches. This process includes independent verification and validation activities.

(3) There was an in-flight anomaly on the GPS–IIF–3 mission in 2012. SMC and AFSPC convened Independent Review Teams, even though the mission was successfully accomplished. The SMC team, which included technical support by The Aerospace Corporation, worked in close coordination with the contractor (United Launch Alliance, ULA) on the investigation, conducting independent analyses and tests where appropriate. The NASA and the NRO also participated in the ULA-led investigation. The AFSPC Independent Review Team complemented the ULA-led anomaly investigation team, provided an independent assessment of the investigation processes and conclusions, and reported their conclusions directly to the AFSPC Commander. The return to flight was granted by the SMC Commander (the certifying official) after Launch Systems Directorate and Delta IV Chief Engineer recommendations to do so, and with concurrence of the AFSPC Commander.

Mr. ROGERS. Considering SpaceX's recent failure with a Falcon 9, are you planning to revisit the certification decision? Why or why not? If there is no root cause identified and final plan to address the problem before the upcoming GPS launch competition, what is your plan?

General GREAVES. (1) Not at this time; SpaceX remains certified for the Falcon 9 Launch System and can compete for and win award of NSS missions.

(2) A failed mission does not automatically drive a revisit to a certification decision or a revocation of a certification. A launch system remains certified unless a significant process or design change, or some other certification factor (such as manufacturing quality), causes the certification authority (SMC/CC) to determined that the launch system or provider is no longer certified.

The Falcon 9 Launch System has flown 18 successful missions prior to the failure. Also, as part of the certification, the USAF assessed and accepted the SpaceX anomaly resolution process, which they are using to determine the root cause of the recent in-flight failure.

(3) Space X expects to arrive at initial root cause findings and implement corrective actions by Fall 2015, which will support the GPS launch competition timelines. If root cause determination and corrective actions are not complete in this timeframe, then the USAF, in support of the GPS launch competition, will evaluate Space X's plan for completing the remaining open non-recurring work, to include work to resolve open flight and qualification anomalies. Regardless of the outcome of the GPS launch competition evaluation, the USAF will continue to observe Space X's technical progress and stay engaged as we do with all certified providers who are addressing technical issues with their launch systems.

Mr. ROGERS. When there is a failure of a launch system, which is the same system to be used national security space missions, should the Department conduct an independent failure review board? Why or why not? What is the historical precedent?

Dr. GRIFFIN. Historically, when a launch system failure has occurred the DOD has always either conducted a failure review under its own auspices, or required total visibility into any failure investigation conducted by its contractors, or both.

QUESTIONS SUBMITTED BY MR. COOPER

Mr. COOPER. To clarify, how much do you estimate the adjustments to Atlas will cost with respect to using an AR1 engine? Is it $100 million-$200 million?

Mr. BRUNO. A U.S. developed engine will not be a pure "drop-in" replacement for the RD–180. Current U.S. technology is not capable of replicating RD–180 performance, and the RD–180 fluid-mechanical thrust vector control (TVC) technology does not exist outside of Russia. None of the variants of the AR–1 under consideration would address these differences.

The current U.S. state of the art allows two near drop-in design options: 1) Almost the same physical interfaces, but lower system performance as a result of reduced engine performance (higher weight, lower efficiency). 2) Same or greater system performance through some vehicle changes to offset lower engine performance.

The minimum set of vehicle/system changes as outlined above for the lower performance option would cost approximately $100M. To enable equivalent or greater Atlas performance the cost would be approximately $200M.

Mr. COOPER. If you pursue the Atlas with the AR1, will you be able to reach the more difficult orbits?

Mr. BRUNO. No, we could not fly the missions that currently require the most capable Atlas variant with 5 solid rocket boosters (Atlas 551). Other missions would require the addition of an SRB making Atlas less competitive.

A less capable Atlas booster when coupled with our planned advanced upper stage (ACES) could not fly the missions that currently require a Delta IV Heavy launch vehicle. ULA would have to continue to offer the more expensive Delta IV Heavy to meet the requirements for these critical national security payloads.

More extensive modifications to the booster to offset the lower engine performance could address these shortfalls, but would increase the total booster development costs to approximately $200M.

Mr. COOPER. Would the BE–4 be available to other launch providers other than ULA?

Mr. MEYERSON. The blue Origin BE–4 engine will be available for purchase by all space launch providers of the United States.

Mr. COOPER. Mr. Griffin stated during the hearing that "It is easily possible to show that SpaceX has received about $3.5 billion or so, possibly more, in open source funding. Seeing as how they have conducted seven launches for NASA, counting the one upcoming this week, that is either an extraordinarily high price per launch of about a half a billion dollars per launch, which I don't believe is the case, or a considerable amount of that money has gone into capitalizing the company. The money was not segregated out, according to Dragon or Falcon 9, so I very strongly believe that the government money which has been provided to SpaceX has in fact gone for the development of Falcon 9." Would you care to respond to this statement or clarify it for the record?

Mr. THORNBURG. Dr. Griffin's testimony merits clarification and correction. To begin, under the Commercial Orbital Transportation Services (COTS) Program, NASA contributed a total of $396M toward the development of a capability to carry cargo to and from the International Space Station (ISS), as well as demonstration missions of that capability. The milestones associated with these payments are publically available. SpaceX invested well more than $450M of private funds toward the development of Falcon 9, including upgrades, and the Dragon spacecraft. To date, beyond the COTS Program, NASA development funds include $75M for CCDev2 and $460M for CCiCap.

SpaceX has operational launch services contracts with a host of international and domestic commercial purchasers of launch services, as well as operational contracts with NASA for cargo missions and satellite delivery missions. Dr. Griffin misunderstands and conflates milestone-based payments under operational launch services contracts versus system development contracts. For instance, SpaceX's cargo contract under NASA Commercial Resupply Services (CRS) is a services, not a development, contract. This service includes the manufacture and launch of a Dragon spacecraft on a Falcon 9 launch vehicle, plus the operations, ISS berthing, reentry, and recovery of the Dragon spacecraft. Pricing for these missions is approximately $130M per mission, on a fixed price basis. SpaceX notes that NASA pays for all of its launches, including those with other providers, under services-based agreements.

Finally, SpaceX recently won a firm fixed price contract, as did Boeing, for astronaut carriage capability development and demonstration missions under the "CCtCap, for a total possible value of $2.6B depending on the number of missions that NASA exercises. Notably, the SpaceX contract includes up to six missions—launches and returns from the Space Station—as well as development. Further, this contract is structured with performance, milestone-based payments. In other words, SpaceX is only paid when it performs contractually agreed-upon milestones (or work) under the contract. SpaceX would note that the Boeing Company received a similar contract with a total value of $4.2B, for performing the exact same requirements. If Dr. Griffin's reasoning were true, which it is not, then the same arguments would apply to Boeing, of course.

SpaceX Falcon 9 pricing for commercial customers is $60M; pricing for U.S. Government missions for satellite carriage is well below $100M.

Mr. COOPER. How will SpaceX plan to fulfill its national security, civil, and commercial missions, and how will you prioritize the missions if necessary, in response to potential disruption to its manifest caused by the recent CRS–7 mission failure?

Mr. THORNBURG. SpaceX currently anticipates returning to flight in the fall of 2015. With respect to prioritization of missions, SpaceX will work with all of our customers to satisfy their needs and meet contractual requirements.

SpaceX maintains a clear manifest policy that is part of each of our commercial contracts, which prioritizes critical U.S. Government missions. Here, SpaceX's Air Force and NASA Commercial Resupply Services (CRS) contracts are rated either DO, DX, or in support of the International Space Station (ISS), meaning that SpaceX has a contractual legal right to prioritize these launches ahead of commercial missions, as necessary. Further, SpaceX has invested internal funds in the development of additional launch infrastructure (i.e. the South Texas launch site and LC–39A at NASA Kennedy Space Center) to eliminate any manifest congestion and any schedule conflicts at the Federal Ranges in the coming years.

Presently, SpaceX is not under contract for any EELV missions; the first competitive opportunity in over a decade is set for release in the coming weeks. The first launch of a competed EELV opportunity would occur no earlier than 2017 based on acquisition and satellite integration timelines.

Mr. COOPER. Can SpaceX describe how it plans to reach the more difficult orbits?

Mr. THORNBURG. The SpaceX Falcon 9 launch vehicle is currently certified under the EELV Program for 4 of the 8 reference orbits for the Program. The four reference orbits for which the Falcon 9 has been certified correspond to upcoming competitive missions in Phase 1A. SpaceX will certify the Falcon Heavy launch vehicle to all eight EELV reference orbits.

Mr. COOPER. What is the right balance in a public/private partnership in terms of funding a new engine? What are the incentives for private industry to develop a new engine and what is the value of planned expenditures by the Department of Defense that these companies would compete for in the national security market once they have developed an engine?

Secretary MCFARLAND. The Department is very supportive of a public/private partnership for the development of a new rocket propulsion system. The actual funding balance between the Department and industry will be based on the evaluation of industry proposals as the Air Force implements its 4-step acquisition strategy. The 4-step strategy allows for an incremental approach to develop new launch capabilities that utilize domestically designed and manufactured rocket propulsion systems and result in systems that meet all the Department's launch service requirements. The Department's goal is to have industry fund the public/private partnership to the maximum extent possible that still supports a positive return on investment for industry. This strategy will enable the Department to transition away from the use of RD–180 engines for National Security Space (NSS) missions in the 2022 timeframe.

At present, the Department is confident that market forces support a public/private investment strategy. Launch service providers will likely be highly motivated to ensure their ability to participate in the future NSS launch market due to the projected mission requirements and the corresponding long-term revenue opportunities. The Department estimates that between now and 2030, which is the currently projected end of the EELV program of record, over $40B in NSS launch services contracts may be awarded.

Mr. COOPER. What is your recommendation for getting best value for the taxpayer money with regard to launch and development of a new engine or launch system, as we seek to ensure access to space while phasing out reliance on RD–180s?

Secretary MCFARLAND. The Department supports the Air Force's strategy for obtaining the best value to the government by implementing their 4-step acquisition process to develop a new launch system utilizing a domestically produced propulsion system. This process allows industry to communicate all alternatives and government to ensure we gain the information required to be a "good customer." The 4-step process also allows for an incremental approach to develop new launch capabilities that utilize domestically designed and manufactured rocket propulsion systems and result in systems that meet all the Department's launch service requirements. This process was also designed to allow the Air Force and industry to optimize the ratio between government/industry investment.

Mr. COOPER. What is the right balance in a public/private partnership in terms of funding a new engine? What are the incentives for private industry to develop a new engine and what is the value of planned expenditures by the Department of Defense that these companies would compete for in the national security market once they have developed an engine?

General HYTEN and General GREAVES. 1) The balance between the Government and private industry will be dependent on each industry solution. Some industry solutions may be mature, but require additional development to meet national security space requirements. In those cases the Government may fund a higher share of the investment. Other solutions may be less mature, but show great promise to both be commercially viable and meet national security launch needs. In those cases, the industry share may be larger. Industry has generally responded favorably to public/private cost share.

2) The primary incentive for industry investment is the ability to capture future market share in both the national security and commercial launch markets. The EELV program plans to procure $36.6B of launch services for National Security Space (NSS) missions from FY18–FY30, and the commercial launch market appears to have a stable demand during that same period. However, if either the Government or commercial market weakens, it may be difficult for industry to achieve their desired return on investment.

Private industry benefits from developing a new or upgraded engine if it is quickly combined with investment to integrate the engine into or develop a domestic commercially viable launch system that allows them to compete for NSS missions. Industry participants will share development costs with the Government, a fact that will help them obtain favorable financing and increase their attractiveness to commercial satellite providers. The goal is a robust U.S. industry for future NSS launch services that is also competitive for the global commercial launch market.

The exact amount of planned expenditures by the Department of Defense for the shared investment portion of these programs depends largely on the solutions proposed by industry, and ultimately, which solutions are selected for Government investment.

Mr. COOPER. What is your recommendation for getting best value for the taxpayer money with regard to launch and development of a new engine or launch system, as we seek to ensure access to space while phasing out reliance on RD–180s?

General HYTEN and General GREAVES. Investing in industry at the launch service level is the best option to quickly and effectively transition off the RD–180 while also meeting program cost, schedule, and performance goals. Specifically, partnering with industry harnesses industry's creative ideas to meet national security launch needs while keeping the Government from bearing the full cost burden. Cost sharing offers the best chance of solving technical challenges and meeting schedule goals. Partnering with industry will also improve assured access to space, because the commercial partners will develop domestic, commercially viable launch systems that meet national security space launch requirements, rather than just a domestic engine that would still require complete launch system development.

The Air Force has developed a four step plan to partner with industry and invest in domestic, commercially-viable launch services. Step 1 is funding the up-front technical maturation and risk reduction. Step 2 is shared investment in industry's proposed rocket propulsion systems. Step 3 expands this shared investment to encompass the entire launch system. Step 4 is to award launch services to certified providers. These four components are not mutually exclusive, and aspects of each may overlap or be conducted in parallel with the others. The goal of this plan is to ensure two or more domestic, commercially viable launch providers that also meet National Security Space requirements and are available as soon as possible but no later than the end of Phase 2 (FY22) or earlier.

Mr. COOPER. What is the right balance in a public/private partnership in terms of funding a new engine? What are the incentives for private industry to develop a new engine and what is the value of planned expenditures by the Department of Defense that these companies would compete for in the national security market once they have developed an engine?

Dr. GRIFFIN. I cannot say what the "right balance" of public/private investment would be for a new engine, as the answer depends in part upon a corporate business-case assessment. I am not privy to any of the internal financial information that the relevant companies would use to make this assessment. However, I will offer the opinion that even if no corporate investment is made in developing a new engine to replace the RD–180 presently employed on the Atlas V, we as a nation should still proceed with this effort. This is a critical national security item, and whether or not a corporate business case can be made for private investment in such an engine, it is needed for U.S. government purposes and should be developed. The projected cost of such an engine, less that $1.5 billion, is considerably lower than even the most optimistic cost estimates associated with grounding the Atlas and moving its present manifest of national security payloads to the Delta 4 family. Replacing the Russian RD–180 with an equivalent American engine is the lowest-cost forward path for the Department of Defense to preserve its national security launch architecture, irrespective of whether any private investment is brought to bear.

Mr. COOPER. What is your recommendation for getting best value for the taxpayer money with regard to launch and development of a new engine or launch system, as we seek to ensure access to space while phasing out reliance on RD–180s?

Dr. GRIFFIN. I believe that "best value" for the American taxpayer would be attained by building, as expeditiously as possible, an American replacement for the Russian RD–180 as it is used on Atlas V. In the meantime, to avoid any gap in our national security space access, we should procure as many RD–180 engines from Russia as that nation is willing to sell.

QUESTIONS SUBMITTED BY MR. COFFMAN

Mr. COFFMAN. Mr. Coffman informed SpaceX that Ms. Shotwell testified in March that DCAA has been working in SpaceX facilities. Mr. Coffman asked if this was a correct statement and SpaceX responded yes. As a follow-up, can SpaceX please describe the audits that DCAA has conducted with SpaceX and how many DCAA professionals are currently working with SpaceX? [Question #15, for cross-reference.]

Mr. THORNBURG. In her March 2015 appearance, Ms. Shotwell testified that SpaceX presently had DCAA auditors doing manufacturing audits. Here, a distinction should have been drawn between DCAA and DCMA. DCAA does not do manufacturing audits; rather, "DCMA" was auditing SpaceX at the time of the Shotwell testimony and has done so annually relative to certain NASA and DOD contracts. Further, DCMA professionals worked on SpaceX's EELV certification for more than a year. Further, SpaceX has provided audited financials and rates to the Government for review. For its part, in the context of the EELV Program, DCAA has performed verification of SpaceX labor rates. SpaceX provides 10–15 in-facility workspaces for U.S. Government officials engaged in contract management oversight, with the division of these seats between NASA, Air Force, DCMA and DCAA, as appropriate and at the discretion of our Government customers with input from SpaceX.

Mr. COFFMAN. Prior to June 28th, During the CRS–1 missions there have been numerous anomalies of both the launch vehicle and spacecraft (Dragon). Out of 6 missions flown, 4 of the Dragon capsules have experienced anomalous behavior, including thruster failure and salt water leakage. Considering that the next evolution (Dragon 2) will be utilized for Crew efforts, and that capsule is anticipated to be re-usable, what is SpaceX doing to mitigate the anomalies that occurred during CRS–1 missions (for missions 1–6)? What "turnaround" activities does SpaceX anticipate performing to ready a previously flown Dragon capsule for a subsequent crewed mission? What specialized readiness reviews will SpaceX and the USG conduct to ensure readiness of the capsule?

Mr. THORNBURG. It is important to understand that anomalies occur on every space mission ever flown. As General Hyten noted in his recent testimony before the committee when asked about launch anomalies: "we've also had the same things with Atlas launches. We've had the same thing with Delta launches. And we go back and look at that."

Dragon has successfully performed missions to and from the ISS seven times. Notably, Dragon is the only operational capsule in the entire world at present capable of carrying significant down-mass from space—all other capsules either burn up on reentry or have highly limited cargo capability. Although Dragon was lost during the CRS–7 mishap, Dragon was not the cause of the failure—and in fact survived a high energy event intact, demonstrating the spacecraft's inherent robustness.

SpaceX's rockets and spacecraft were designed from the beginning to carry crew with built-in redundancies throughout, including avionics with triple-string computing, engine-out capabilities on both Falcon 9 and Dragon, and an integrated escape capability, which unlike past abort tower systems, provides astronauts with escape capability all the way to orbit. SpaceX and NASA conduct robust post-mission analyses with a focus on continuous improvement of our systems and vigilance regarding safety and mission assurance.

One of the best ways to validate safety systems is through actual flight testing. With our cargo version of the Dragon spacecraft, SpaceX is able to test the vast majority of systems designed to keep astronauts safe well before any astronaut actually flies. This provides a distinct advantage to not only meet NASA's safety requirements, but ultimately, with NASA's support, build the safest and most reliable human spacecraft ever flown.

There is no agreement in place with NASA to fly "previously flown" Dragon capsules for subsequent crewed missions. SpaceX and Boeing have contracts with NASA under the CCtCap program that dictate the reviews necessary prior to crewed missions.

Mr. COFFMAN. Falcon Heavy is 3 years delayed on original commitments. In 2011 Elon Musk stated that, "Falcon Heavy will arrive at our Vandenberg, California launch complex by the end of next year, with liftoff to follow soon thereafter. First launch from our Cape Canaveral launch complex is planned for late 2013 or 2014." In March of 2015 SpaceX testified that Falcon Heavy would finally fly, "later this year."

Considering the delayed schedule and the recent letter of intent submitted regarding the certification process of Falcon Heavy, how does SpaceX plan to mitigate the schedule gap? Why is Falcon Heavy 3 years behind schedule?

Mr. THORNBURG. SpaceX submitted its updated EELV certification statement of intent (SOI) for the Falcon Heavy on April 14, 2015. SpaceX has timed Falcon Heavy development and demonstration to precede our contractual obligations for the operational launch of the vehicle. Contractual commitments are the gaining factor here. The first launch contract for Falcon Heavy—for STP–2, an Air Force mission—was pushed back as a result of a delay with the Government's COSMIC–2 payload. Accordingly, SpaceX was in a position to move back our self-funded demonstration flight of the Falcon Heavy, while focusing on EELV certification of the Falcon 9 launch vehicle and other matters.

SpaceX anticipates flying a Falcon Heavy demonstration flight in the first half of 2016, well in advance of the vehicle's first contracted missions. We have additional commercial Falcon Heavy flights under contract in 2016. Falcon Heavy will be ready for any planned Phase 2 EELV missions years ahead of their anticipated launch dates, scheduled to begin no earlier than 2020, and will have numerous flights in advance of any EELV mission that the vehicle might be used to perform.

Mr. COFFMAN. The Mitchell Study recommended stockpiling RD–180 engines to smooth the transition to an American made system but current legislation prohibits such a stockpile. Given the recent failure of SpaceX's Falcon 9, do you believe Congress should relook at the timelines and numerical restrictions imposed on the use of the RD–180?

General HYTEN and General GREAVES. This anomaly does not alter the Air Force's position with respect to the RD–180 restrictions. The Air Force maintains assured access to space via two launch vehicle families per U.S. law and Presidential policy. This is currently provided by United Launch Alliance's (ULA) Atlas V and Delta IV launch vehicles. However, the Air Force is reintroducing competition into the Evolved Expendable Launch Vehicle (EELV) program. ULA's Atlas V vehicle is their lowest-cost offering when compared to the Delta IV vehicle, thereby providing competitive prices until new launch vehicles are available, likely no earlier than 2021. Additional RD–180s will be required in order to maintain assured access to space at a reasonable cost to the Government.

Excluding heavy lift missions in EELV Acquisition Phase 1A and Phase 2, the Atlas V is capable of lifting approximately 9 and 25 missions, respectively, for a total of approximately 34 missions. However, we believe authorization to use up to 18 RD–180 engines in the competitive procurement and award of launch service contracts through Fiscal Year 2022 is a reasonable starting point to mitigate risk associated with assured access to space and to enable competition. As the competitive environment develops and evolves, we will re-assess the number of engines required to ensure we maintain assured access to space.

Mr. COFFMAN. The Mitchell Study recommended stockpiling RD–180 engines to smooth the transition to an American made system but current legislation prohibits such a stockpile. Given the recent failure of SpaceX's Falcon 9, do you believe Congress should relook at the timelines and numerical restrictions imposed on the use of the RD–180?

Dr. GRIFFIN. I am absolutely of the opinion that our present legislative quota on the import and stockpiling of the RD–180 engine is far too low. While I strongly believe that we should end our dependence upon Russia for this engine as soon as it is possible to do so, we should not "cut off our nose to spite our face" in the attempt. Continued use of the RD–180 until we have a domestic replacement is the best course of action available to us at this point, and I offer that opinion irrespective of the status of Falcon 9. Even if the recent failure of that vehicle had not occurred, most payloads manifested on Atlas could not be launched on Falcon 9, as its payload capacity is relatively limited for the foreseeable future. Our national security space launch requirements cannot be fully met without Atlas, and for the next 5 years Atlas cannot launch without the RD–180.

QUESTIONS SUBMITTED BY MR. BRIDENSTINE

Mr. BRIDENSTINE. In a worst case scenario, the United States could find itself reliant on a single provider for national security space launches. If that sole U.S. provider failed, then America could lose access to space for national security payloads. Given the possibility of such a scenario, are there any launch vehicles currently provided by close allies which can cover a broad range of EELV-class missions?

Secretary MCFARLAND. A waiver to National Space Transportation Policy and statute would be required to launch a National Security Space (NSS) payload on a launch vehicle not manufactured in the United States. Even if such a waiver was granted, significant engineering analysis would be required to determine what, if any, NSS payloads would be compatible with an allied nation's launch vehicle. At present, no allied launch capability has a demonstrated capability that meets all NSS requirements. While it is possible to evolve this capability, NSS payloads would need to be assessed for compatibility.

Mr. BRIDENSTINE. In a worst case scenario, the United States could find itself reliant on a single provider for national security space launches. If that sole U.S. provider failed, then America could lose access to space for national security payloads. Given the possibility of such a scenario, are there any launch vehicles currently provided by close allies which can cover a broad range of EELV-class missions?

General HYTEN and General GREAVES. Public Law 111–314 (51 U.S.C. 50131) and National Space Transportation Policy require National Security Space (NSS) systems be launched using United States commercial providers. Currently, assured access to space for NSS missions is provided by United Launch Alliance (ULA) with the Delta IV and Atlas V. The SpaceX Falcon 9 recently completed certification to compete for NSS launch services. While it is possible that other allied systems could launch a subset of NSS missions, the detailed studies have not been accomplished to ensure we can meet all NSS stressing requirements. If all domestic paths to space are precluded, the Air Force would consider all options, in consultation with the Congress, to regain access to space as quickly as possible.

QUESTIONS SUBMITTED BY MR. BROOKS

Mr. BROOKS. Both the U.S. Air Force and ULA have asserted to this committee that it will require approximately $200 million to integrate AR1 into the Atlas V. You, however, stated to the committee that the cost to do so would be in the tens of millions. I am wondering why there is such a large discrepancy.

Are we comparing apples to apples—or apples to oranges? How so? In your view, what vehicle are the Air Force and ULA referring to when they cite an AR1 integration cost of $200 million? What vehicle are you referring to when you cite an AR1 integration cost of "tens of millions?"

Ms. VAN KLEECK. The $200 million figure ULA refers to is the estimated cost to develop a proposed "Vulcan/AR1" launch vehicle. While Vulcan/AR1 would be a derivative of the current Atlas V, it is envisioned by ULA that this new launch vehicle would have an approximately 30% greater propellant load. Integration of an AR1 engine main propulsion system is included in that value. Vulcan/AR1 is not to be confused with Vulcan/BE–4, which represents a wholesale change of the launch vehicle and infrastructure from kerosene propellant to methane (Liquefied Natural Gas, or LNG) propellant. Mr. Bruno, in his testimony, acknowledged that Vulcan/BE–4 would cost $600M–$800M. Aerojet Rocketdyne's work with ULA on the AR1 engine and an AR1 main propulsion system—comprised of two AR1 engines mated together—has revealed that no major modifications to the Atlas V launch vehicle are required to integrate the AR1 as a replacement for RD–180 booster engine. Aerojet Rocketdyne estimates the non-recurring costs to integrate the AR1 engine main propulsion system into the existing Atlas V launch vehicle to be between $50 million and $75 million, including launch vehicle integration and certification costs.

Mr. BROOKS. Is there precedent for re-engining a launch vehicle, particularly the Atlas? Please elaborate for the committee.

Ms. VAN KLEECK. Yes, there is a strong precedent for re-engining launch vehicles, including the Atlas. Most recently, as the Atlas evolved from the Atlas IIAS to the Atlas III, the vehicle was re-engined from the Rocketdyne MA5 engine to the Russian-made RD–180 engine. Throughout its history, the Atlas program has made incremental changes rather than wholesale launch vehicle changes, to include stretching the onboard tanks, avionics changes and engine changes. The incremental evolution of the Atlas system maintains mission success with far less risk than an entirely new launch vehicle and the required accompanying infrastructure changes.

Similarly, in the civil space arena, the Antares launch vehicle is currently undergoing a re-engining from the AJ26 (derived from the Russian NK–33 engine) to the Russian-made RD–181 booster engine.

Mr. BROOKS. What would be the cost to integrate AR1 into the current existing version of Atlas V? Upon what do you base this cost estimate? Has this estimate been shared with ULA?

Ms. VAN KLEECK. Aerojet Rocketdyne estimates the non-recurring costs to integrate an AR1 engine main propulsion system into the existing Atlas V launch vehicle would be between $50 and $75 million. This estimate includes launch vehicle integration, infrastructure mods and certification. Our estimate is based on: 1) Aerojet Rocketdyne's two decades of work on the oxygen rich staged combustion cycle, previous internal company and U.S. government investment, and advances in materials science and manufacturing techniques, 2) an engine designed to integrate into the Atlas V with minimal changes required. This estimate has been shared with ULA.

Mr. BROOKS. What would be the range of payloads the current Atlas V with an AR1 booster engine could launch to geosynchronous transfer orbit (GTO)? What number and type of expected NSS payloads would such a configuration be unable to launch?

Ms. VAN KLEECK. The Atlas V featuring an AR1 engine main propulsion system would provide similar performance to the existing Atlas V, including coverage of all USAF EELV missions currently served by Atlas V. The same Atlas V/AR1 combination however would not be able to launch missions currently flown on the Delta IV Heavy.

Mr. BROOKS. Would re-engining the Atlas V with AR1 allow for a faster, less costly and lower risk transition off of the RD–180? If yes, how so? If not, why not?

Ms. VAN KLEECK. Yes, coupling the AR1 engine in a main propulsion system comprised of two AR1 engines mated together onto the Atlas V offers the fastest, lowest cost and lowest risk approach to the U.S. government. The AR1 engine has been designed from the start to minimize launch vehicle modifications to the current Atlas V. Building on Aerojet Rocketdyne's long history of successfully developing rocket engines for the Nation, the AR1 features advanced oxygen-rich staged combustion technology, is an all U.S. design, provides a 500,000 lbf thrust class that is configurable to multiple U.S. launch vehicles—including the 1 million lbf thrust AR1 main propulsion system for the current Atlas V—leverages the existing liquid oxygen-kerosene launch infrastructure, operations and facilities and utilizes new materials and advanced manufacturing techniques, like additive manufacturing. Aerojet Rocketdyne developed the last major U.S. liquid rocket engine, the RS–68 that powers the Delta IV launch vehicle, in five years. Similarly, Aerojet Rocketdyne is on course to complete development, undergo certification and bring the AR1 into production by the end of 2019—5 years after initiation of dedicated development.

Mr. BROOKS. How has Aerojet Rocketdyne gained the knowledge and experience to build an engine that will leapfrog the Russian technology used in the RD–180 engine? Over what time period did you execute this work?

Ms. VAN KLEECK. Aerojet Rocketdyne's development of a new American liquid rocket engine, the AR1, is not a new program in Fiscal Year 2015. Since the 1990s, Aerojet Rocketdyne has been working on Oxygen Rich Staged Combustion (ORSC) technology. ORSC is the combustion cycle that will be used in the AR1. More than two decades of technology efforts support the rapid development of this advanced engine. AR1 leverages over $300 million in government and Aerojet Rocketdyne company investments. AR1 will be a thoroughly modern rocket engine using the latest engineering analysis, manufacturing techniques, and advances in materials science. As an example, Aerojet Rocketdyne materials science research and development has enabled us to develop an oxygen resistant material to eliminate the need for the coatings that the Russians used in earlier designs. Through the use of modern electronics, AR1 will also forego the need for the hydraulic "step ladder" actuation that is used in the RD–180. Aerojet Rocketdyne is also employing additive manufacturing techniques to develop state of the art, world class launch engine components at an affordable price for the government customer.

Additionally, Aerojet Rocketdyne currently participates in two existing competitively won contracts to perfect ORSC technology: NASA's Advanced Booster Engineering Development and Risk Reduction Program (ABEDRR) and the U.S. Air Force's Hydrocarbon Booster Technology Program (HCBT).

Mr. BROOKS. Dr. Griffin stated that as NASA Administrator he funded development of the Falcon rocket. To SpaceX, how much money has NASA invested in SpaceX development efforts since inception of the company? If SpaceX is unable to answer, would DCAA be able to assist in the evaluation of USG funds paid to SpaceX?

Mr. THORNBURG. Dr. Griffin was referring to the Commercial Orbital Transportation Services (COTS) program, which was initiated under his tenure during the Bush Administration.

Under the Commercial Orbital Transportation Services (COTS) Program, NASA contributed a total of $396M towards the development of a capability to carry cargo to and from the International Space Station, as well as demonstration missions of that capability. Your question pertains to development alone. SpaceX went beyond this to both develop and demonstrate. The milestones associated with these payments are publically available. SpaceX invested well more than $450M of private funds toward the development of Falcon 9, including upgrades, and the Dragon spacecraft. To date, beyond the COTS Program, NASA development funds include $75M for CCDev2; and $460M for CCiCap.

SpaceX recently won a firm fixed price contract, as did Boeing, for astronaut carriage capability development and demonstration under CCtCap, for a total possible value of $2.6B. Notably, the SpaceX contract includes up to six missions—launches and returns from the Space Station—as well as development. This contract is structured with performance, milestone-based payments. In other words, SpaceX is only paid when it performs contractually agreed-upon milestones (or work) under the contract. SpaceX would note that the Boeing Company received a similar contract with a total value of $4.2B, for performing the exact same requirements.

SpaceX has operational launch services contracts with a host of international and domestic commercial purchasers of launch services, as well as operational contracts with NASA for cargo missions and satellite delivery missions.

Mr. BROOKS. Can SpaceX provide a technical description of how the Falcon vehicle and propulsion system can meet all 8 of the EELV reference missions to, as Representative Cooper described, the appropriate orbits?

Mr. THORNBURG. SpaceX would be pleased to brief the Congressman on the technical aspects of the Falcon family of vehicles, in the appropriate forum. In short, Falcon 9 is certified to execute missions associated with 4 reference orbits, and Falcon Heavy will be certified to all 8 reference orbits. The Air Force will validate that these requirements will be met as part of the EELV certification process.

Mr. BROOKS. SpaceX stated that any government funding should be matched 50/50 by commercial investment. Can SpaceX verify that this 50/50 split was the case for the development of Falcon and Dragon? If SpaceX is not able to verify, would DCAA be able to assist in the evaluation of the proper use of USG funds?

Mr. THORNBURG. Under the Commercial Orbital Transportation Services (COTS) Program, NASA contributed a total of $396M toward the development of a capability to carry cargo to and from the International Space Station, as well as operational demonstration missions of that capability. As noted above, under the COTS program, SpaceX contributed 53% of the development funds. The U.S. Government contributed $396M under this program; SpaceX invested well more than $450M of private funds toward the development of Falcon 9, including upgrades, and the Dragon spacecraft.

Mr. BROOKS. In the hearing, the term Low-Price Technically Acceptable (LPTA) was mentioned. In light of the SpaceX accident and considering the value of national security payloads, can you describe the risk that is required to compete launches with a LPTA selection criteria? In the long run and beyond current budget challenges, is LPTA worth the risk to the tax payer and to the warfighter? What criteria will the USG use in assessing a proper balance between price and technical acceptability?

Mr. THORNBURG. The Air Force and the Department of Defense are responsible for development of source selection criteria associated with Requests for Proposals. SpaceX cannot comment on the criteria that the USG will use in assessing price and technical acceptability. SpaceX notes that NASA and a number of other agencies, as well as the entire commercial world, purchase launches services on a commercial fixed-price basis. Further, DOD itself has purchased LPTA launch services in the recent past. Launch should be treated as a commercial commodity and, based on this, the appropriate FAR contracting models should apply, as required by law.

Mr. BROOKS. Can you please describe how the SpaceX accident on the June 28th will impact the schedule and selection criteria for the upcoming GPS III mission competition?

Mr. THORNBURG. The Air Force and the Department of Defense are responsible for the schedule and selection criteria for the upcoming GPS III mission competition. According to public reports, the Air Force has stated that it plans to issue the RFP for this mission in the coming weeks. SpaceX looks forward to participating in this competition—the first competition held in the EELV Program in the last ten years.

QUESTIONS SUBMITTED BY MR. TURNER

Mr. TURNER. Knowing that Atlas V and Delta IV rockets are the two systems currently capable of meeting the full gamut of national security payload requirements, what is the Department's existing backup plan should there be a catastrophic failure or disruption preventing either system from being used?

At this year's Space Symposium in Colorado Springs, you mentioned your concerns with using an unproven system to launch some of our nation's most critical and costly satellites. If the United States is faced with a scenario in which a backup system is immediately needed, are there proven systems currently being used by NATO allies that could serve as viable alternatives?

It's my understand that Europe's Ariane 5 rocket is a proven system capable of heavy-lift launches and slated to be the launch vehicle for the James Webb Space Telescope—the most sophisticated and costly telescope ever built. Given its track record, could the Ariane 5 serve as a viable backup to both the Atlas and Delta systems?

General HYTEN. Public Law 111–314 (51 U.S.C. 50131) and National Space Transportation Policy require National Security Space (NSS) systems be launched using United States commercial providers. If all United States commercial providers are precluded, the Air Force would consider all options, in consultation with the Congress, to regain access to space as quickly as possible. Preliminary studies based on open source information indicate that the Ariane 5 launch vehicle is capable of meeting the requirements for some NSS missions.

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