Speaking Event Information Form
Lt Gen Greaves

Event:	Air Force Association's Mitchell Institute for Aerospace Studies Breakfast Series: "*Value of Space to the Warfighter*"
Location:	Capitol Hill Club
Date:	Friday, Feb. 19, 2016 - 11:30 a.m.
Time / Format:	20-30 minutes remarks + 15 mins Q&A
Audience:	MLAs, Press, other staff

Good morning, everyone.

Thank you, Steve Kitay for that kind introduction. It's great to be in Washington DC again and meet our distinguished members.

Thank you, Peter Huessy, and thanks to the folks of the Air Force Association for making this another great event. I am honored to be invited back, and it's a real pleasure to sit with you and provide some thoughts on our space launch capabilities.

Space assets have been a key element of warfighting for over 30 years. They provide a unique vantage point to observe activity around the globe; relay terrestrial communications; and provide precision position information.

Our satellites provide mission-critical global access, persistence and awareness for our national security and have become vital to the global community and world economy.

Air Force space capabilities, and the Airmen who operate them, are foundational to our nation's ability to deter aggression and affect global impact across the entire range of civil and military activities, from humanitarian efforts and disaster relief to major combat operations.

Our Airmen acquire these space capabilities and operate these missions. They are a key part of our strategic competencies.

From contracting, to training, to the complete set of life cycle management responsibilities, I am honored to represent the Air Force's Space and Missile Systems Center—home to over 5,000 men and women comprised of uniformed military, government civilians, Federally Funded Research and Development Centers (FFRDC) personnel, and support contractors.

SMC is over sixty-years in the making—that's over two generations of remarkable work pioneered by General Bernard Schriever—at a place we call "The Birthplace of Military Space".

Thanks to our mission-focused workforce at SMC and our industry partners at ULA and SpaceX, we successfully delivered nine (9) space launches in 2015, these include:

- Two Mobile User Objective System (MUOS) satellites, to significantly improve ground communications for our forces on the move
- Three GPS satellites, delivering unprecedented accuracy to the warfighter and to users around the world
- One Wideband Global SATCOM (WGS) satellite to fortify our communications infrastructure around the globe
- Two NSS launch missions

- And the DSCOVR mission for NASA and NOAA

Our great work continued in 2016 with two successful launches so far this year. This month alone, this team successfully launched the final spacecraft of the GPS Block IIF system and the NROL-45 spacecraft into their intended orbits all within five days of each other.

Simply stated, this is another bright indication of the great work performed and mission executed by all at SMC and our mission partners.

Now, a message to our government and contractor workforce: Thanks for all you continue to do and please ensure you remain focused on the task at hand—maintaining mission success; even as the deliberations on the future take place here in Washington.

Where We Are Today

If you look at where we are today, thanks in large part to the efforts of the men and women of the Air Force Space Command, the Air Force, our contractors, and our mission partners, our space capabilities have multiplied the effectiveness of our forces in the land, sea, air, and cyber domains. This includes worldwide precision navigation and timing; protected strategic and tactical communications; wideband communications; Overhead Persistent Infrared Capabilities (OPIR); and weather information provided from our space assets.

Our dependence on space systems for both military and civilian uses is growing. Without these space-based capabilities, today's military operations would be significantly more costly (or unaffordable) to our force structure and national security.

The importance of space capability to our national defense has never been more critical in our history. Space systems, along with advances in other warfighting domains, have enabled us to continue meeting our national objectives and provide combatant commanders with air, space, and cyberspace options to meet the threat.

Our launch systems have enjoyed continuous successes over the last two decades. While our priority has been to maintain mission success, it should be noted that the Evolved Expendable Launch Vehicle program (EELV), which has an outstanding performance record to date, has been far more affordable than its predecessors in the 1980s and 1990s. For comparison, if we had continued to use our legacy Titan IV, Delta II and Atlas launch vehicles, it would cost about $117 billion in FY12 to launch the EELV manifest. The current EELV program estimate to launch that same manifest is $54 billion in FY12, reflecting an astounding 53 percent savings over the average cost of the legacy systems available in 1990s.

Our mission success remains paramount; but we are also focused on resilience, which for launch means launching when and where we need to.

We've achieved our mission success record with rigorous Government mission assurance techniques leveraging robust contractor processes.

We approach launch resilience through a policy of Assured Access to Space. We implement this by maintaining at least two reliable launch systems, capable of launching National Security Space satellites for continued access to space, should one suffer a grounding event.

Our Assured Access to Space policy supports our warfighters; and we search for space launch affordability, risk management, and competition among launch service providers.

To give you some background, the Department of Defense is both guided and constrained by law and

policy in how we develop, acquire, and sustain national security space launch capability. As codified in Title 10, Section 2273 of the US Code and in the President's National Space Transportation Policy, the DOD is tasked to provide assured access to space.

As mandated by Title 10, assured access to space requires *"the availability of at least two space launch vehicles (or families of space launch vehicles) capable of delivering into space any payload designed by the Secretary of Defense or the Director of National Intelligence as a national security payload."*

Let me re-emphasize, we are working within the FY15 and FY16 NDAA and adhering to the law.

Launch Strategy—Where We Are Heading

So, when it comes to national security space, we follow three priorities:

- One, mission focus on the current and future state of our business, our industry, and our programs
- Two, maintaining resilience in our launch capability, which we meet through a policy of Assured Access to Space, and
- And three, supporting competition, when it is feasible, as mandated by law and policy

The Department's intent is to assure that we support healthy competition in building a dominant space force for the current and next generation launch services—because competition is also required by law, but also to help control cost and encourage innovation in launch technology.

This is key!—By investing in industry's launch systems, we leverage industry's investment, which not only offers the best chance of solving technical challenges to meet schedule goals, and provides the opportunity to harness the industry's creative ideas, but closes the business case to allow industry to use their commercial systems to provide launch services that meet our more stressing National Security launch needs.

The DOD's overall Evolved Expendable Launch Vehicle (EELV) investment acquisition goals are:

- Two or more domestic, commercially viable launch service providers that also meet national security space requirements in order to provide and solidify US assured access to space to service all eight (8) reference orbits
- Transition off the RD-180 engine to eliminate reliance on foreign engines for the EELV program
- And, support the US launch industry's commercial viability in the global market to the extent possible

Through Requests for Information (RFIs) with industry in Fall 2014 and Spring 2015, we reviewed the launch business environment to determine how to achieve this strategy. The responders to this RFI included a wide variety of launch service providers and engine providers. What we found was that:

- Engine development is necessary, but engine development alone does not improve assured access to space, we also need to team up with industry partners for launch system development
- Therefore, significant launch system development with launch service providers is required to use a new engine

Assured access to space requires end-to-end space launch capability, and not just a rocket engine. It

requires the engine and the rocket to work together. Simply put, just replacing the RD-180 engine with a new engine will not deliver the same performance of the current design of any rocket. In fact, it may result in a system that delivers less payload to orbit at a higher cost.

The fact of the matter is, the Department does not buy rockets or engines. We do not buy launch systems or propulsion systems. What we buy is the transportation of our satellites to the required point in space by launch service providers.

- First, the Atlas V system was built around the RD-180 engine to deliver a specific range of payloads into a variety of orbits. So any effort to replace the RD-180 engine with a substitute engine would require extensive engineering design, changes, and testing, and would ultimately result in a sub-optimized launch system, that would still require recertification. For example, if the engine and launch system are not designed together, the launch system could end up with a lower performing main stage that requires additional strap-on engines to give the launch system enough initial boost to get to a place where the second stage can take over. Each additional strap-on engine is another bill the Government has to pay.
- Second, replacing the engine itself would be expensive. Our current estimates are that this would take about $2 billion to $3 billion for a replacement.
- Third, a copy of the RD-180 engine replacement for the Atlas rocket would likely not be of general use to the commercial launch service community; and it may be viewed as likely helping one specific launch service provider.
- And lastly, we need assured access to space through multiple reliable, affordable, and efficient launch service providers.

We are therefore pursuing and requesting approval to transition to investment in the full launch service. In the meantime, we are moving forward by investing in Rocket Propulsion Systems (RPS) efforts, while fully complying with the FY15 and FY16 statutory direction.

Rocket Propulsion System Development

In compliance with Section 1604 of the 2015 NDAA and Section 1606 of the 2016 NDAA, the Air Force is investing in domestic next-generation Rocket Propulsion Systems (RPSs) suitable for national security use by 2019 and transitioning away from the use of the Russian-supplied RD-180 engines.

Section 1604 also states that the RPS be available for purchase by all domestic launch providers, and it must be developed using full and open competition. Let me expand on that with further details.

In order to get to a domestic solution and transition off the Russian made RD-180 propulsion system, we have funded Risk Reduction & Technology Maturation efforts with $60 million of the $220 million authorized in FY15, in addition to $41 million from FY14.

We started this immediately, starting in January 2015, while we were assessing our overall way forward because we knew we needed to get our Government, academia, and industry started on this. For over a year, we have been collaborating with NASA, the national labs, universities, and industry to mature fundamental engine technologies to advance technology, ease the design process, and reduce the cost of manufacturing engines.

Between November 2015 and January 2016, we awarded ten Booster Propulsion Technology Maturation Broad Agency Announcement (BAA) contracts supporting Risk Reduction and Technology Maturation

for rocket propulsion system development.

The Department's overall portfolio of investments through this BAA include Material Manufacturing and Development, primarily focused on reducing the cost of future engines, and Advanced Technologies, primarily focused on advancing the state of the art for future engines.

- The first award under the BAA was to Johns Hopkins University for Evaluation of "Additively Manufactured Liquid Rocket Engine Cooling Channels" to improve performance in next-generation rocket engine thrust chambers and cooling channels.
- The second award was to Tanner Research Inc. for "Solid Rocket Motor (SRM) Ignition System with Built-In Test (BiT)" to develop an ignition system that can simplify detection of defective solid rocket motors.
- The third award was to Johns Hopkins University for "Performance Sensitivity of Rocket Engine Cooling Channels" to address industry knowledge gaps in propellant characteristics to enable Liquefied Natural Gas (LNG)/Methane booster engine development.
- The fourth award was to Moog Inc. for "Non-Destructive Evaluation, Standards, and Testing" to develop additive manufacturing technology for propellant control valves for use in a wide range of liquid engine systems.
- The fifth award was to Orbital ATK for "Segmented Composite Case Advanced Technology" to focus on reducing weight of solid rocket motor case joints and improving reliability.
- The sixth award was to Aerojet-Rocketdyne for "Additive Manufacturing Qualification Process for Reduced Booster Propulsion Life Cycle Cost" to develop a qualification process for additively manufactured engine parts that do not currently exist.
- The seventh award was to Northrop Grumman for "Turbopump Assembly Additive Manufacturing" to improve technological readiness of an additively manufactured Liquid Oxygen (LOX)/Methane booster engine Turbopump Assembly (TPA) for insertion into a rocket propulsion system.
- The eighth award was to Boeing for "Additively Manufactured High Pressure Engine Dome" to develop a full scale, complex, thick-walled engine component that advances additive manufacturing state of the art, and is targeted for integration into an engine development.
- The ninth award was to Arctic Slope Technical Services for "A Low Cost, High Performance Preburner for Oxygen Rich Staged Combustion (ORSC)" to develop a preburner that implements a "continuous dilution" approach to minimize preburner exit thermal gradients to enhance system reliability and reduce life cycle cost.
- The tenth and final award was to Northrop Grumman for "Duct-cooled, Carbon Silicon Carbide (C/SiC) Thrust Chamber Technology" to demonstrate both new manufacturing technology and a new nozzle cooling approach that will lead to a lighter combustion chamber design that is less expensive to produce.

These acquisitions will mature booster propulsion technology and reduce risk for the US industrial base, paving the way for domestic propulsion systems and their associated launch systems.

Also in response to Section 1604 of the FY15 NDAA and (subsequently) Section 1606 of the FY16

NDAA, the Air Force released an RFP for Rocket Propulsion System Prototype Investments last summer (in June 2015).

We are investing the remaining $160 million of FY15 funding and a portion of the FY16 funding in industry's Rocket Propulsion Systems. The FY16 NDAA authorized $228 million to be used toward the same effort in Rocket Propulsion Systems and launch vehicle interfaces.

Our investments are in new Rocket Propulsion Systems that launch providers plan to use to provide future launch services using launch vehicles that are commercially viable but can also launch national security satellites, which would benefit the entire industry. This is important since launch systems solely designed for commercial systems may not meet National Security Space requirements for heavier payloads and various orbits.

Earlier this year, the Air Force awarded two of up to four Other Transaction Agreements (OTAs) that invest Government funds in industry's rocket propulsion system development. These competitively awarded commercial-like agreements leverage on-going investment by industry in rocket propulsion systems. The OTAs require shared investment with each company but in return give the companies the flexibility to develop these systems using commercial best practices.

One RPS OTA was awarded to SpaceX for the development testing of the Raptor upper stage rocket propulsion system, which will provide additional capability to the Falcon 9 and Falcon Heavy launch systems to meet our national security space requirements.

The other RPS OTA was awarded to Orbital ATK for development of the Common Booster Segment main stage, the Graphite Epoxy Motor (GEM) 63XL strap-on booster, and an extendable nozzle for Blue Origin's BE-3U/EN upper stage engine.

Our efforts in Risk Reduction, Technology Maturation, and OTAs are part of a planned Rocket Propulsion Systems in the Launch Service Investments (LSI) that are not only commercially viable, but can also launch all national security payloads.

Launch Service Investment

Our main focus going forward will be on launch service investments via innovative public-private partnerships with launch service providers to provide launch services that use domestic propulsion systems.

With the support of Congress, these launch service investments will begin in FY17. As the systems become certified, we will provide on-ramps so launch services using non-allied engines will be replaced by new systems as they become certified to launch NSS missions. After all the systems are developed, in 2022 or 2023, we will transition to a strategy of sustained competition where assured access to space is obtained by leveraging a domestic launch industry with at least two commercially viable launch providers.

The DoD is absolutely committed to transitioning off the RD-180 as quickly as possible while minimizing impacts to national security.

Our investment in launch service acquisition activities will enable us to reach the ultimate goal of two or more domestic, commercially viable launch service providers that meet the National Security Space launch requirements. We must do this as soon as possible, with the support of Congress.

Assured Access to Space during the Transition to New Launch Services

What many may not realize is that all of today's EELV-class launch systems are the result of successful

public-private partnerships. In the late 1990s, the Air Force provided Lockheed Martin and Boeing $500 million dollars each to develop the Atlas V and Delta IV launch vehicles. Both companies funded the remainder of the multi-billion dollar development costs. Similarly, in the late 2000s, NASA initiated the Commercial Orbital Transportation Service (COTS) program where they similarly invested in SpaceX's Falcon 9 and Dragon cargo vehicle and Orbital ATK's Antares with the Cygnus cargo vehicle.

Historically, it has been shown that public-private partnerships can be leveraged to obtain reliable space launch services at reasonable costs. It's a very exciting time, where new commercial applications of space, including large constellations in low earth orbit and global internet services, are projected to increase the demand for launch services.

We are using the lessons learned from the original EELV and NASA COTS public-private partnerships in our planning for the Launch Service Investment to provide the flexibility to ensure these partnerships will pay off even without major growth of commercial launch demand.

The Atlas V and Delta IV launch vehicles have an unprecedented record of mission success, which were accomplished under the Evolved Expendable Launch Vehicle (EELV) program. So the expectation for future launch services is to maintain this level of mission success across the board.

However, according to ULA, the Delta family is not commercially cost competitive, and the restrictions of the RD-180 engines limit the use of the Atlas V configuration. Therefore, we must look for alternative launch capabilities that are compliant with the law, and assure the availability of at least two space launch vehicles.

SpaceX Failure and Certification Status

On May 26, 2015, we announced SpaceX's Falcon 9 Launch System was certified for National Security Space (NSS) launches with Falcon 9 v1.1 as the baseline. This certification takes into account the entire Secretary of the Air Force's spring 2015 Independent Review Committee's recommendations. The main recommendation was to allow new entrant certification with some open work, provided there are jointly approved work plans in place that support potential NSS mission processing timelines.

The certification process provides a path for launch-service providers to demonstrate the capability to design, produce, qualify, and deliver a new launch system and provide the mission assurance support required to deliver NSS satellites to orbit. SpaceX is now eligible for an award of specified NSS missions, in accordance with the Certification Letter, to include competing for the GPS III-2 launch service.

As you are all aware, there was a Falcon 9 commercial launch that experienced an in-flight mishap, resulting in the loss of vehicle on June 28, 2015.

An official investigation was led by SpaceX and the Federal Aviation Administration (FAA) Anomaly Investigation Team (AIT) completed its investigation and presented findings to FAA in November last year and submitted their final report. The 45th Space Wing authorized the return to flight operations from a Range Safety perspective in December.

The FAA officially closed the investigation on Dec. 9, 2015 based on their oversight during the investigation and review of the final report.

SMC is also conducting an independent assessment of the mishap and the SpaceX investigation, due to be completed in March 2016. Any corrective actions will be addressed as part of the Air Force's established mission assurance processes.

The mishap did not affect the certification status of the SpaceX Falcon 9 v1.1 launch system. SpaceX returned to flight on Dec. 21, 2015, with the successful launch of the commercial ORBCOMM-2 mission.

Since its initial certification, SpaceX has evolved their Falcon 9v1.1 configuration into the Falcon 9 Upgrade.

To update the certification baseline, SpaceX and the Air Force built Joint Work Plans for the verification and demonstration of design changes, with a detailed Integrated Master Schedule. On January 25, we announced the certification of the Falcon 9 Upgrade.

We are working with other New Entrants and look forward to future certifications of new or upgraded launch systems.

To Summarize

Space is no longer benign; it is evolving to a more contested environment, with more operational limitations.

We can no longer take for granted the relative peace we've enjoyed for nearly 60 years. There are over a dozen nations out there yearning to replace our space superiority.

We all know how space capabilities contribute to our warfighters and the nation. There is not a day that goes by that we are not dependent on operations from space and cyberspace. Economic prosperity, national prestige, and national security depend on operations conducted in these domains.

The work we do is vitally important in keeping us safe. The missions we operate are crucial in ensuring the safety of America. It makes me proud to work alongside the incredible men and women of SMC and you, our industry partners, to deliver these lifesaving capabilities to our nation. And none of this is going to be possible without the combined efforts of all of us.

All of us here in government and industry need to maintain that same laser focus on mission success across the board. The joint force demands it and we will deliver!

Thank you again for inviting me to come and share my passion on space and space launch.