The Case for Domestic Rocket Engine Procurement

Chris Beauregard

George Washington University, Space Policy Institute, 1957 E St. NW Washington, DC, 20057
Corresponding author: beauregard@gwu.edu

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Executive Summary Russian-built rocket engines have occupied an integral role in American and international access to space, including the International Space Station and national security and commercial satellite launch operations since 2000, when they were first utilized on the Atlas III rocket. The technology was initially developed as a result of Soviet Union innovation during the Cold War and has resulted in an engine superior to the previous American alternatives in performance, cost, and reliability. Seeking a dependable and cost-effective option, the United States House and Senate have, on several occasions in recent years, voted to continue the import and use of these engines- a significant accord, given other proposed sanctions, strained relations and competitive nature of the two space race stalwarts. The deal marked a substantial milestone in international cooperation but has since created a major point of contention, in light of recent geopolitical developments and advances in the private commercial spaceflight industry. In a hasty response to heightened tensions in 2014, the engines were then temporarily banned for military use by the United States, but again permitted when it became apparent how crippling such a ban would be to national security entities. The episode acted as a tipping point in the search for a domestically produced alternative and such a candidate is nearing selection. The successful implementation of a domestic rocket engine transition will require cooperation between public and private entities in an effort to balance diplomatic relations with national security concerns and an interest in fostering American technological progress to further the growth of a domestic commercial launch industry. By measuring risks, effectively appropriating funding and avoiding swift political action without prior consideration of the consequences, policymakers can ensure an outcome that balances all constituent interests. However, a premature transition may initiate an even more disastrous vacuum in US-based launch capabilities. With such dire consequences, it is imperative to phase the transition over a period of several years to attain the necessary confidence interval and still retain an adequate stockpile of legacy components for emergency use.

I. Examining the American Launch Industry Reliance

To understand the perspective of the U.S. launch industry, it is important to understand what has led to the competitive landscape and current role of Russian rocket engines in the market. Much of the discussion centers around United Launch Alliance (ULA), a joint venture between Boeing and Lockheed Martin that utilizes the Russian-built engines as the first stage of their Atlas V rocket, a workhorse launch vehicle, especially for national security-related payloads. The most significantly used engine, known as the RD-180, is the successor to the RD-170 engine which was initially used in Soviet Launch operations as a strap-on booster to increase initial launch thrust. The engine was then scaled down and marketed as a standalone first stage engine, evolving in the early 1990s as a means to ensure the United States government and commercial launches in the Evolved Expendable Launch Vehicle (EELV) and Atlas programs. The production rights were acquired by General Dynamics Space Systems, which was then absorbed by Martin Marietta and merged with Lockheed Corporation to become Lockheed Martin. The initial intent of the U.S. government was to have production of rockets related to national security launches built by Pratt & Whitney, a US-based United Technology Corporation company. However, all production has continued to occur in Russia through RD AMROSS, a joint venture between Pratt & Whitney and NPO Energomash, a Moscow-based company primarily held by the Russian government.[1] This contract is set to expire in 2018 and has, thus far, provided ULA and Lockheed Martin with seventy RD-180s engines, including twenty in 2015 alone, in an effort to ensure provisions until the early 2020s.[2] As of April 2016, the RD-180 has propelled sixty-eight launches, with only one failure, the highest success rate in the industry by a sizeable margin.

Procurement of Russian rocket engines has also contributed to the business model of Orbital ATK, an American corporation created by the 2015 merger of the space systems company Orbital Sciences and the defense giant Alliant Techsystems (ATK). Before the merger, Orbital Sciences' Antares rocket was propelled by Russian-made NK-33 rocket engines, initially produced by the Soviet entity, Kuznetsov Design Bureau. These engines were then imported to the US, modified by US-based Aerojet Rocketdyne (created by a 2013 acquisition of Pratt & Whitney Rocketdyne by Aerojet of Sacramento), and redesignated as AJ-26 engines to fulfill Orbital's contractual obligations with NASA to provide cargo resupply services for the International Space Station. However, as NK-33 engines are no longer manufactured by Kuznetsov, a stockpile from the Cold War-era was accumulated in an effort to secure reliable launch capabilities. A subsequent Orbital Sciences effort to purchase RD-180 engines from NPO Energomash was blocked by ULA, based on their contractual supply agreement, resulting in a $515 million lawsuit based on allegations "that ULA's exclusivity agreement with RD AMROSS violated the U.S. Sherman Antitrust Act and that ULA's alleged monopolization of medium-class payload missions violates section four of the Clayton Antitrust Act."[3] A proposed solution involved Aerojet Rocketdyne co-producing NK-33 engines with the Kuznetsov successor, NK Engines Co., to provide Orbital with a new and ongoing stock[4]. The lawsuit was subsequently dropped, but Orbital ATK's implementation of the new engine failed catastrophically when an October 28th, 2014 commercial resupply launch of the Antares launch vehicle resulted in an explosion shortly after liftoff and loss of the vehicle. The AJ-26 engine was listed as the probable cause[5] and dropped from future launches. Orbital Sciences then opted to pursue a long-term contract with NPO Energomash for between twenty and sixty RD-181 engines (a variation of the existing RD-191 engine) in the following months for their second generation Antares.[6] The Antares II successfully launched and delivered its payload to orbit on October 17, 2016, and Orbital ATK has purchased an additional quantity for upcoming missions planned through 2019, as well as a stock of RD-181s for testing purposes.

This supporting perspective, while providing the essential information to contextualize the current issues, is a dense history of the manufacture, supply, and launch mergers and transactions. To better frame the ongoing and upcoming decision-making processes, a deeper working knowledge of these technology choices is necessary.

II. Validity of the Existing Technologies

The RD-180 and RD-181, having been heavily relied upon by United Launch Alliance and Orbital ATK, have been without domestic alternative or competitor for most of their history. The basis for these ongoing production contracts has been a combination of price, performance, reliability, and availability, as well as geopolitical considerations. The cooperative agreements have involved incredibly valuable intellectual property and have led to nearly two decades of mutual success between public, private and international partnerships, despite an initial wariness of reliance on a foreign technology and diplomatic risk.

As a result of substantial Cold War-era funding of rocket engine research and development, the Soviet Union made major technological advances in liquid rocket engines, which influenced their proficiency in engines that utilize kerosene and liquid oxygen (LOX). This contrasts from historical rocket development in the United States, which has focused more heavily on cryogenic engines and solid propellant motors that were utilized by the long-standing Space Shuttle program.[7] As a launch vehicle first stage, the Russian-developed engines have proven themselves as a higher-performance option. The engine's efficiency resulted in an Atlas V designed specifically for use with the RD-180, which was further supplemented by U.S.

government encouragement of private enterprise cooperation with Russian organizations to promote diplomacy and greater cost-efficiency. The RD-181, initially utilized by Orbital Sciences, was chosen for their second generation Antares launch vehicle due to improvements upon the previously used engines, enabling 20% more cargo per flight, while fitting the same size and shape profile, thus allowing Orbital Sciences to retain their original vehicle design. [8]

Engine cost was also a significant decision point at the time of initial agreements, as well as in the current commercial launch arena. According to the Deputy Defense Secretary Robert Work, the financial commitment to develop a comparable American alternative would be \$1.5 to \$5 billion over a six year period.[9] The Pentagon considers RD-180s indispensable to maintain launch schedules and a similar sentiment is maintained by ULA, as they would be unable to compete for any commercial or government launches, potentially driving them out of business. Additionally, the RD-180 engine has proven itself as a more reliable option for several reasons. First, the increased performance allows a decreased number of engines utilized per booster, providing fewer error-prone interfaces. For the earlier iterations of the Atlas rocket, such as the Atlas IIAS, up to six Lockheed Martin MA-5 engines were used, as opposed to a single RD-180 engine used in the Atlas III.[10] Furthermore, the engine had already flown over twenty-six times in launches of the Russian Zenit vehicle, allowing engineers to perform necessary modifications during its break-in period before adoption by ULA.[11] Finally, the engine has proven substantially easier to integrate, as many of the bolt-on components used in previous launch vehicles are now delivered pre-installed by NPO Energomash.

Price and performance aside, the Russian rocket engines are frequently utilized for national security-related launches, as they provide the lift capability necessary to launch larger satellites typically used by organizations such as the Department of Defense, National Geospatial-Intelligence Agency, and United States Air Force. Since the Cold War, the space industry has remained one of the few cooperative relationships between the two superpowers and the ongoing rocket engine production agreements have enabled levels of transparency and trust on both ends that would otherwise be unachievable. In addition to International Space Station operations, the rocket engine agreements have aided diplomatic efforts through cooperation and influenced U.S. policy on a grander scale, including nonproliferation measures. It has also been asserted that access to Russian launch capabilities enables continued operation of U.S. satellite reconnaissance missions, a capacity that cannot be forgone.[12] These benefits, however, are not without stern opposition and geopolitically fueled causes for concern. In a 2014 U.S Air Force study, it was determined that reliance on this engine poses a national security risk," and that "few near term options to mitigate future risks were found."[13] As Russia has continued to exert its influence upon neighboring territories, U.S. policymakers and defense officials have advocated for a curtailing of ongoing cooperation.

III. Ongoing Diplomacy and Availability Concerns

The international political climate was adversely affected by recent Russian military interactions, specifically those in Crimea, which have prompted sanctions between Washington and Moscow. These tensions occur amid Russia's announced exit from the International Space Station, in which they are a major partner and the amicable relationship now hangs in the balance, especially in the eyes of a handful of elected officials and senior-level defense personnel. Senator John McCain (R-AZ), the chairman of the Senate Armed Services Committee, has remained a fervent opponent of any reliance on Russia, especially for national security-related launches, and has even accused those who support such reliance of corruption. In 2014, the military use of Russian engines was temporarily banned by Congress after the Russian annexation of Crimea, though this ban was slightly eased to prevent the failure of ULA, the solely capable launch provider for many government entities.[14] An additional concern noted by McCain is the involvement of Dmitry Rogozin, Russia's Deputy Prime Minister and defense and space industry head, who was individually sanctioned after the Crimean conflict. Heavy criticism has also fallen on the rocket engine "middle-man" RD AMROSS, a Florida-based subsidiary of Roscosmos, Russia's government-owned space program. In 2014, AMROSS had only five employees, yet netted \$100 million in profits on markups on pass-through costs, which were deemed exorbitant.[15]

To complicate matters further, tensions with the U.S. during the 2014 Ukraine conflict prompted Rogozin to forbid supply of rocket engines for U.S. military-related launches.[16] Additionally, the RD-180 and RD-181 programs must also adhere to international traffic in arms regulations (ITAR) to prevent the sharing of sensitive U.S.-based technologies with Russian counterparts. Accordingly, any business to be conducted with foreign entities must be approved by the United States government.[17] A similar agreement exists for Russian government contractors, preventing much of the operational improvement that would otherwise occur over the course of use in domestic programs.

IV. State of the Procurement Process for American Alternatives

To solicit potential replacements for the Russian engines, the U.S. Air Force produced a June 2014 study seeking "booster propulsion and/or launch system material options that could deliver cost-effective, commercially viable solutions for current and future National Security Space (NSS) launch requirements. Air Force Space Command (AFSPC) is now considering an acquisition strategy to stimulate the commercial development of booster propulsion systems and/or launch systems for Evolved Expendable Launch Vehicle (EELV)-class space lift applications."[18] Subsequently, two public-private partnerships were created to design, build and test the replacement engine by 2019 with shared funding from USAF and the competing contractors. The first is a joint partnership of ULA and Blue Origin, a launch company backed by Amazon CEO Jeff Bezos, which was already in its third year of development for the BE-4 engine.[19] United Launch Alliance CEO Tory Bruno has also stated that ULA plans to offer an option for a US-built version of the RD-180. The second partnership is between Aerojet Rocketdyne, which has been seeking funding to develop its AR-1 engine, and Dynetics, an American-based engineering firm.[20] Both the BE-4 and AR-1 engine are being developed with the anticipation of powering ULA's next generation launch vehicle, Vulcan, as well as the current vehicles. According to Bruno, the apparent first choice for ULA is an integration of Blue Origin's BE-4 engine, which is believed to be more than half way through the five to seven-year engine development period. The structure of its parent company, Blue Origin also makes the option especially appealing, as Blue Origin is well-funded and does not rely on government contracts in a way that many other engine makers do, essentially operating from an endowment created by owner Jeff Bezos.[21]

Another practical long-term consideration is the American production of RD-180 engines. According to ULA's Tory Bruno, "We certainly could domestically produce RD-180s if we wanted to do that. We are in fact looking at that possibility because, although the RD-180s will become banned after a certain point of time for national security space missions, there are no restrictions on using them for NASA or other civil or commercial applications." It is a well-founded idea considering that RD AMROSS has obtained from NPO Energomash over 100,000 documents detailing all required information to produce the engines, including "engineering drawings, design specifications, certification design documentation, and manufacturing documentation, in addition to materials data, test data and tooling documentation."[22] A potential production factory location has even been discussed by ULA in Decatur, Alabama.[23] However, though RD AMROSS has received the necessary documents to manufacture the engines under a license agreement, it is not quite as simple to supply the decades of tacit knowledge involved in the process, which is required for successful reproduction.

An additional contender for the U.S. launch market, SpaceX, has grabbed headlines for much of the past decade with plans for travel beyond earth orbit and impressive feats of engineering progressing towards those goals. A relative newcomer to the national security launch sector, SpaceX was recently certified for national security launches and has pursued government contracts to supplement its private enterprise and long-terms goals, touting their ability to provide launches at a steep discount compared to other providers. Their strategy to obtain a market share has included embroiling themselves in the ban of Russian engines, adding legal pressure to the Department of Defense with accusations of permitting a launch monopoly to ULA, despite ULA being the only capable launch provider until SpaceX was certified. In addition to the monopoly debate, SpaceX representatives also alleged that funds from the RD-180 program were supporting members of the political elite within Putin's presidency. Furthermore, the timing of Russia's conflict in Crimea was particularly appealing to SpaceX, as it added to their argument for a ban on Russian engines which would effectively disable the prime launch contractor, ULA.

In response, the House and Senate voted in favor of continuing use of RD-180s until 2022, based, in part, on lobbying efforts, but also careful deliberation of the impacts that a launch industry without RD-180s would have on national security efforts.[24] The concept was heavily debated on Capitol Hill, but Florida Senator and senior Armed Services Committee Bill Nelson was able to aptly advocate for ULA's perfect launch record, also noting that rocket engines composed less than one-third of one percent of U.S. imports from Russia and that they are a negligible source of funding for Moscow. Finally, and most importantly, Nelson communicated that American-made replacements would not be ready until 2022- a long wait for launching sensitive military satellites. The result was a compromise in policy that limited purchase of Russian engines after a specific date rather than the immediate future.[25]

V. Short- and Long-term Policy Recommendations

A nation's launch capabilities can be stratified into three levels: independent, autonomous and guaranteed. At an independent level, a nation operates its own launcher which may rely on foreign sources of supply. An autonomous capability is similar, in that a nation operates its own launcher, but also commands full control of all technologies and components involved in the process. Finally, a guaranteed level of capability supplements the autonomous capability with additional operational launchers with no technological commonality between them. It is at this level of launch capability that a nation is most resilient, as it does not need to rely upon foreign launchers, foreign suppliers, one single vehicle or one single company to assure access to space. Even if one launcher is grounded or experiences a catastrophic accident, there are still redundancies in place to protect space interests and assets without any shared technology between them. The gradation to a guaranteed capability would normally require a nation to proceed from one step to the next. However, by instituting a reliance on the RD-180, the United States has left itself exposed by attempting to bypass step two.[26]

At this juncture, it would not be reasonable or fiscally responsible to ban Russian-produced rocket engines outright. First, costs would skyrocket, as launching large payloads on other options would be prohibitively more expensive and could include reliance on other foreign entities, including Russia. Additionally, some of the other options available are not truly capable of placing satellites into the required orbits. For example, though SpaceX has been recently certified to carry military payloads, they are unable to reach several of the critical military orbits.[27] Essentially, by banning Russian rockets prematurely, the United States government would cost taxpayers billions of dollars and, in the process, undermine its military and intelligence capabilities.

A practical, responsible and effective long-term policy must balance American commercial interests as well as those of national security stakeholders, with an added incentive of international diplomacy. With this in mind, a responsible method to move forward includes retaining the existing framework for production and delivery of RD-180s from NPO Energomash through RD AMROSS for use with ULA launch vehicles until at least one alternative has proven itself as equally reliable. To be proven as roughly comparable in reliability, the new engines should complete a trial phase of at least twenty successful launches to achieve a desirable confidence level, though, after seven or so successful launches, it would become appropriate to transition the national security payloads to such a launch vehicle.[28] In analyzing risk versus the cost of such a program, it is important to understand that many of the payloads being launched on national security missions exceed $1 billion, excluding the cost of launch, which is usually 15-25% of that figure. In this case, the risk level is prescriptive to the Department of Defense budget, which has historically valued performance and reliability over cost. It can, therefore, be assumed that even an optimal level of risk- one that minimizes the sum of consequences- is too precarious for national security launches and thus, a nearest-to-zero tolerance must be pursued.

Additionally, once the transition has been made and RD-180s are phased out from continued service, they must be stockpiled for use in emergency situations with the design of future launch vehicles accommodating for that contingency. For the next decade at least, RD-180s will be the most familiar launch hardware and cannot be allowed to disappear entirely. The United States Air Force estimates that eighteen engines are needed to maintain their Atlas V schedule through 2022.[29] With that number in mind, an ongoing stockpile buffer of five years' worth of launches is necessary to support national security launches. For any amount of effectiveness to be imparted by this policy recommendation, budgetary increases are necessary. In addition to Department of Defense investments in obtaining an American-made engine alternative, funds should also be invested in acquiring and maintaining the stockpile of Russian-made engines. Such financial commitments would ensure a plurality of options for access to space, negating a scenario in which national security interests are eschewed for budgetary reasons. Despite the age of such equipment, launch operations and production teams are more familiar with the RD-180, as opposed to new hardware. In an analysis of space-related accidents - specifically, the Apollo program - newly developed systems impart a much higher risk, especially when the advances are based on greater complexity and created with adaptations of previous systems.[30] In this context, the refurbished or newly American-made RD-180s can initially be considered less reliable than Russian counterparts, requiring additional oversight in their use. This oversight would be best applied by a government entity, such as the Federal Aviation Administration that already regulates much of the commercial spaceflight launch process, by employing the expertise of former specialists and current mechanics with tacit knowledge of Russian rocket technology. This type-certification process could be instituted similarly to the FAA-moderated testing of commercial aircraft components by employing manufacturer engineers to assess and verify the reliability and risk of such designs.[31]

VI. Conclusion

For the United States to retain a position of power in space-based defense and intelligence capabilities, it must regain and retain assured access to space. The concept of assured access specifies that, by law, two independent systems must be available to launch payloads upon demand to accommodate for rapidly changing priorities and a shifting geopolitical climate. Until recently, ULA has operated as the sole launch provider capable of fulfilling that requirement through their Atlas and Delta vehicles, and they remain the only company with a proven capability for more difficult launch profiles. In this new and highly competitive commercial launch market, the assured access policy will be accomplished through the competition of multiple providers fighting for their share of the missions with the hope that there is enough market demand to support two launchers. It is only with an all-encompassing understanding of the contributing domestic and international factors that effective and responsible decisions can be made by policymakers. And, while a politically complex reliance on a foreign supplier is not an ideal scenario, it must be understood that such an option is vastly superior to having zero launch capabilities.

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Author Biography

Chris Beauregard is a second-year graduate student at the Space Policy Institute at George Washington University's Elliott School of International Affairs, where his research interests include space policy and commercial activity. In 2017, he served as a program management intern at the United Nations Office of Outer Space Affairs, a visiting scholar at the European Space Policy Institute in Vienna, Austria, staff assistant to Dr. Scott Pace at the Space Policy Institute and communications coordinator for the Space Generation Advisory Council. In addition to his studies, he is assisting GW's Micropropulsion and Nanotechnology Lab with regulatory compliance for the launch of the University's first satellite, GW-Sat.

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