Fact Sheet:
Russian Rocket Engines used by the United States

As the Russia-Ukraine crisis has flared, and East and West have instituted sanctions against one another, some in government and the media have begun questioning whether utilization of Russian manufactured rocket engines to launch U.S. space missions could be jeopardized as a consequence. Some members of Congress have called for reconsideration of the use of these rocket engines. The U.S. Air Force initiated a review of whether reliance on this engine poses a national security risk in May 2014. The study determined that the loss of the RD-180 would leave a significant impact. Few near term options to mitigate future risks were found.

Given the importance of this issue and its potential impact on a critical part of America's space industrial base, the Space Foundation has prepared this fact sheet in order to clarify the nature and scope of America's reliance on Russian rocket engines.

Which Russian rocket engines are in use within U.S. space launch programs?

RD-180

- The RD-180 engine, manufactured by NPO Energomash of Russia and marketed in the U.S. by RD AMROSS (a joint venture between Pratt & Whitney and NPO Energomash), is used by United Launch Alliance (a joint venture of Lockheed Martin Corporation and The Boeing Company), as the first stage engine to power the Atlas V rocket.

RD-181

- The RD-181 engine, manufactured by NPO Energomash, is used by Orbital Sciences Corporation to power its Antares rocket on resupply missions to the International Space Station.

What is the heritage of these two engines?

RD-180

- The RD-180 is based on the RD-170/RD-171 engines. The RD-170 was used in the Soviet-era Energia launch vehicle -- which had only two launches. The RD-171 engines are still in service on various versions of the Ukrainian/Russian Zenit rockets; these are used by Russia for some government launches and also by the Sea Launch and Land Launch companies that perform commercial satellite launches. General Dynamics' (GD) Convair Division originally developed the Atlas rockets. GD-Convair was acquired by Martin Marietta in 1994, which in turn merged with Lockheed Corporation to form Lockheed Martin. The company negotiated the rights to use the RD-180 as a first stage engine for the Atlas rocket -- initially to launch commercial satellites and later as part of the Department of Defense's Evolved Expendable Launch Vehicle (EELV) program. The original intent was for the RD-180 to be produced by NPO Energomash for commercial satellite launches and by Pratt & Whitney (a subsidiary of United Technologies Corp.) for U.S. Government launches, but to date all engines have been produced in Russia.

- The Russian company Energomash develops and manufactures liquid propellant rocket engines. It manufactures the RD-180 engine in Khimki, near Moscow. It is procured and delivered to the U.S. by RD AMROSS, a joint venture of Pratt & Whitney and NPO Energomash formed in 1997. Since 1999, approximately 70 RD-180 engines have been delivered to Lockheed Martin and United Launch Alliance by RD AMROSS. Both Pratt & Whitney and NPO Energomash are contracted by RD AMROSS to support the engine integration onto the Atlas rocket, prelaunch, day of launch and post launch technical activities. The current contract delivery of RD-180 engines expires in 2018, unless new orders are issued by United Launch Alliance to RD AMROSS.

- RD AMROSS has rights to produce the RD-180 in the U.S. under license arrangements with NPO Energomash. The technical, manufacturing and related information to produce the RD-180 was received by RD AMROSS in the U.S. many years ago and preliminary work was performed by Pratt & Whitney to demonstrate key technologies, processes and engineering capabilities.

RD-181

- The RD-181 is based on the RD-170 engine. It is a variant of the single-chambered version, the RD-191. Two RD-181 engines are used on the first stage of the Orbital Sciences Corporation's Antares rocket. Engine modifications include a need for heated nitrogen to evacuate their combustion chambers of air prior to ignition.
- The RD-181 is manufactured in the same Khimki factory as the RD-180s used by United Launch Alliance.

What are the technical and performance characteristics of each engine?

- Historically, the Russians focused and sought to optimize the performance (efficiency) of their liquid rocket engines, including kerosene/liquid oxygen (LOX) engines specifically through the development and refinement of the Oxygen-Rich, Staged Combustion (ORSC) engine cycle. After the conclusion of the Apollo program, the U.S. primarily focused on hydrogen-based liquid rocket engines and solid propellant motors—driven by the development and sustainment of the Space Shuttle program and Strategic Missile development. The Russian ORSC engines have proven to be particularly efficient as first stage rocket engines for launch vehicles.

<u>RD-180</u>

- The RD-180 uses a kerosene (RP-1)/liquid oxygen (LOX) propellant combination. It is a dual-combustion chamber, dual-nozzle design and can be throttled for more or less thrust at various phases of flight. The engine produces up to 860,000 lbs of thrust at sea level.

<u>RD-181</u>

- The RD-181 also uses an RP-1/LOX propellant combination. Its design incorporates a single combustion chamber and nozzle. It provides 28% more thrust than its predecessor, the AJ-26. The engine produces 432,000 lbs of thrust at sea level.

Why were these engines selected?

- <u>It should be noted that utilization of Russian engines was not a strictly technical decision, but was also tied into US government policy in the aftermath of the collapse of the Soviet Union. Namely to engage the Russian aerospace industrial base in a peaceful manner to assist in larger non-proliferation efforts.</u>

<u>RD-180</u>

- The Atlas V was designed around the performance provided by the RD-180. At the time of its development in the 1990s, the RD-180 was technologically advanced compared to the state of U.S. RP-1/LOX technology. Further, the U.S. Government was encouraging aerospace companies to explore partnerships with their Russian counterparts, as a matter of diplomatic policy and with an eye toward lower costs. The use of a Russian engine was initially allowed by the U.S. Government with the expectation that the engine would eventually be co-produced in the U.S. for

American government missions, while all-Russian engines would continue to be used for commercial launches.

RD-181

- Orbital opted to switch from the AJ-26 to the RD-181 because it will permit the Cygnus spacecraft to deliver 20% more cargo than its predecessor. The RD-181 uses the same combustion cycle and same mixture ratio between propellants as the AJ-26 engines, and they are the same size. Orbital is able to keep the same design of the Antares. The engines propellants provide the optimal performance necessary after the 2014 mishap. There is no comparable alternative in the U.S. that provided similar thrust and specific impulse.

What are typical payloads for the launch vehicles using the Russian engine?

RD-180

- The RD-180 engine supports the full gamut of Atlas V missions including military communications, intelligence collection, missile warning, planetary exploration, as well as earth science payloads, a few commercial satellites, and possible human spaceflights in the future.

RD-181

- The primary mission of the Antares launch vehicle is to place into orbit the Cygnus cargo resupply spacecraft, which Orbital builds to service the International Space Station. Orbital is pursuing future commercial satellite launches and possible military satellite launches using Antares.

How many engines have flown for each program?

RD-180

- The RD-180 has flown 68 times -- 62 on Atlas V, with one failure, and six on the Atlas III, with 100% success. A single RD-180 powers the first stage of the Atlas V and the first stage of the now-retired Atlas III.

RD-181

- The RD-181 has not flown on the Antares yet. The first mission using the RD-181 is planned for August 2016.

How many engines are at present in inventory?

RD-180

- United Launch Alliance has stated that it has purchased 20 new engines in 2015 in order to keep the Atlas V flying into the early 2020s.

RD-181

- Orbital has ordered 20-60 RD-181s from Energomash. As of February 2016, Orbital had 4 RD-181 engines in possession for testing purposes. As of March 2016, Orbital procured a further eight RD-181 engines from Energomash.

Is there an existing immediate U.S. alternative?

RD-180

- There is no existing U.S. alternative to the RD-180 that can be accessed immediately.

RD-181

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From the point of view of the U.S. operator: what would be the short and long term impacts, both positive and negative, if that engine became no longer available to the U.S. company?

- In the near term, both ULA and Orbital have at least a two years supply of their respective Russian sourced engines.

- The U.S. Government and industry have invested approximately $300M over the last 20 years in technology associated with ORSC engines. The Department of Defense estimates it would need $1 billion over five years to establish production of an RD-180 class engine on U.S. soil. Meanwhile, if the supply is interrupted, some missions could be offloaded to the Delta IV while Pentagon officials prioritize what missions need to be flown on the Atlas V. (The Delta IV uses the RS-68 engine, manufactured by Aerojet Rocketdyne; the RS-68 is a U.S. engine, develops 663,000 pounds of thrust at sea level, and uses Liquid Hydrogen (LH2) and LOX for fuel.)

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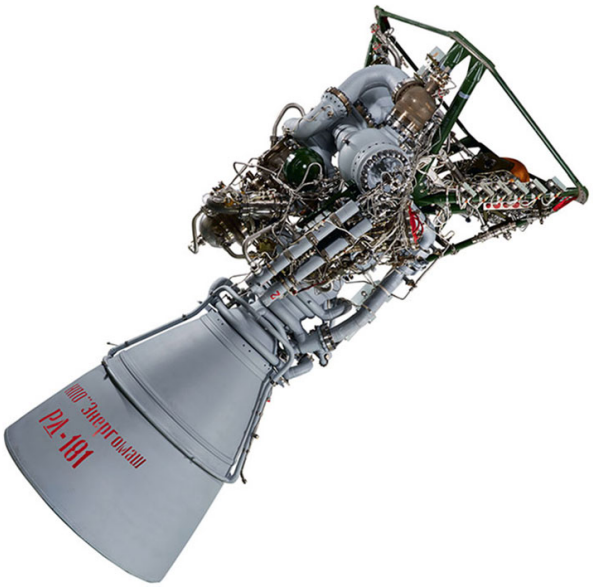
RD-180
Credit: Energomash



RD-181

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