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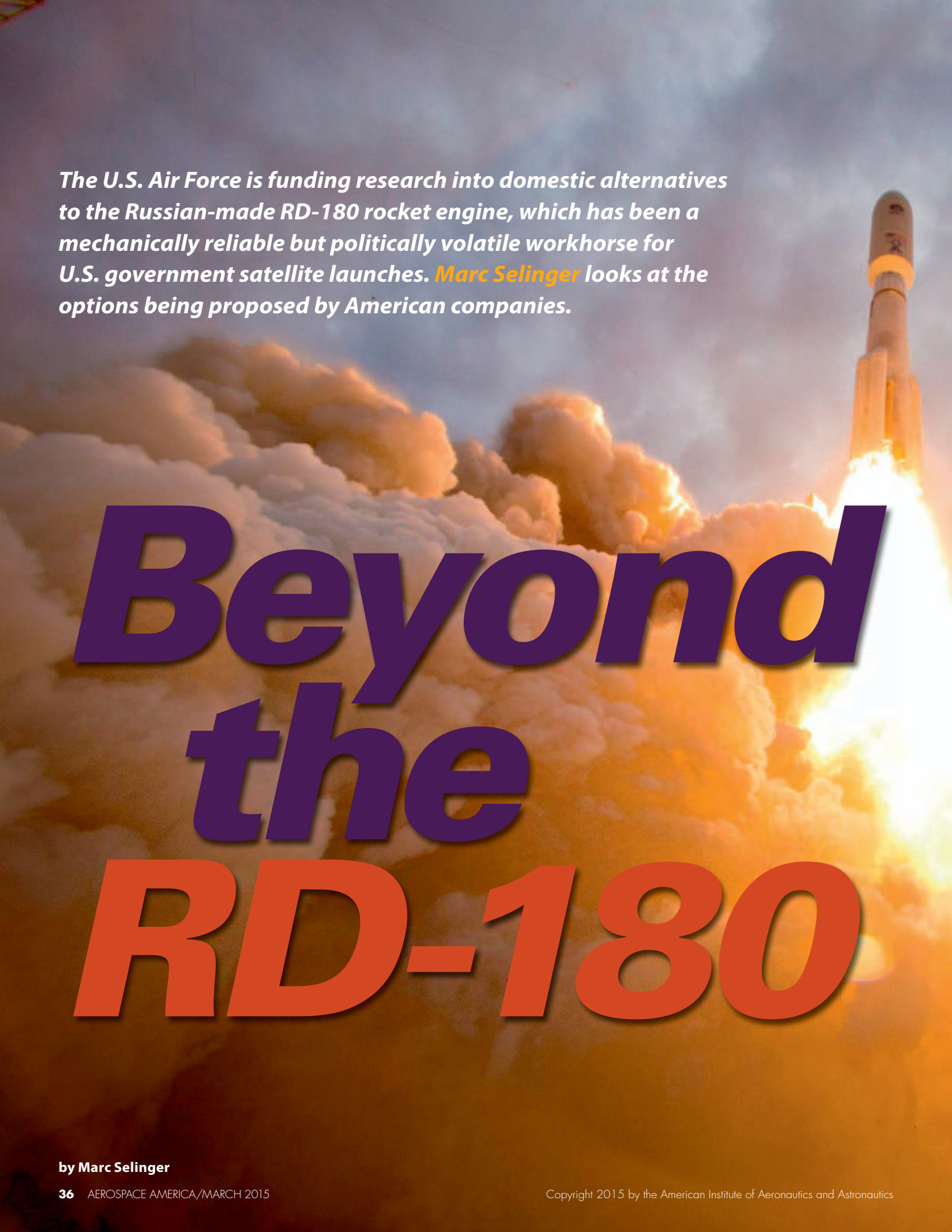

The U.S. Air Force is funding research into domestic alternatives to the Russian-made RD-180 rocket engine, which has been a mechanically reliable but politically volatile workhorse for U.S. government satellite launches. Marc Selinger looks at the options being proposed by American companies.

Beyond the RD-180

by Marc Selinger

The 20-story rocket stood in the evening darkness on a Florida launch pad in January, ready to transport a military communications satellite into space. Shortly after 8 p.m. the countdown ended: "five, four, three, two, we have RD-180 ignition and we have liftoff of the United Launch Alliance Atlas 5 rocket carrying the third Mobile User Objective System mission for the United States Navy," an announcer declared, flames roaring from a single Russian-supplied main engine.

The satellite reached orbit safely, continuing the Atlas 5's near-flawless launch performance since its 2002, but bringing the U.S. a step closer to running out of RD-180s to power the Atlas 5s.

Rising tensions over Ukraine prompted the U.S. to impose economic sanctions on Russia, and Moscow in turn threatened to cut off RD-180 supplies to the U.S. for national security launches. Fed-up members of Congress responded by directing the Air Force to develop an American-made engine.

The Air Force is now engaged in a high-stakes undertaking to define the best way to end reliance on RD-180s before the stockpile of roughly a dozen runs out. Such a development could, in theory, strand spy satellites and communications spacecraft on the ground.

U.S. defense officials say they could have new engines ready in time to avoid delays in satellite launches, but the Air Force still must deliver on that promise, and designing a new engine is, after all, rocket science.

In August, the Air Force told industry it would also be open to "alternative launch vehicles."

The RD-180 "provides a unique blend of reliability and power," says William Ostrove, an aerospace/defense analyst at Forecast International. "It is definitely possible to design a new engine, but it will take time and money to do that."

An Atlas 5 powered by an RD-180 main engine lifts off from Cape Canaveral Air Force Station in Florida in July 2013.

ULA

Options abound

The Air Force used the opportunity of its fiscal 2016 budget request to underscore that it wants to consider more than simply installing a different kind of engine or engines on the Atlas 5s. It said it wants to line up at least two "commercially-viable, domestically-sourced" space launch providers. August's request for information will be followed later this year by a request for proposals exploring a broad range of options, including mixing in other American rockets for national security launches.

As for the new engine options, the Air Force said it would consider many variables, including the cost and time involved in engine development and how much seed money industry is willing to invest.

To jump start engine development, the Air Force has budgeted $513 million through fiscal 2020, including $220 million that Congress provided in the 2015 omnibus appropriations act signed into law in December. To date, early engine work involves research in such areas as components, materials and manufacturing processes, budget documents indicate.

"We need to continue to mature those key technologies while at the same time bring forward an acquisition strategy and plan," Maj. Gen. Roger Teague, director of space programs in the Air Force acquisition office, told reporters at a space budget briefing in February. "We are continuing to look at all sources of supply, as well as all vehicle type configurations, whether it be liquid or solid."

Competitors for a new propulsion system include two liquid oxygen/kerosene engines, Aerojet Rocketdyne's AR1 or SpaceX's Merlin; Blue Origin's BE-4 liquid oxygen/methane engine; and an Orbital ATK solid-fuel engine, says Ostrove, the analyst. Orbital ATK was formed in February with the completion of the merger of Orbital Sciences Corp. and the aerospace and defense groups of Alliant Techsystems.

Aerojet Rocketdyne and Blue Origin have been doing engine development work for years that they say could pave the way for an RD-180 replacement by 2019.

ULA, a Boeing-Lockheed Martin joint venture that provides Atlas 5 and Delta launch services to the government, an-

Two potential RD-180 alternatives are the planned Aerojet Rocketdyne AR1 (left) and the Blue Origin BE-4. The liquid oxygen/kerosene AR1 would produce 500,000 pounds of thrust and could be configured for the Atlas 5, Aerojet Rocketdyne says. The BE-4, which would produce 550,000 pounds of thrust with liquid oxygen/liquefied natural gas, is being developed by Blue Origin and United Launch Services for ULA's next-generation rockets.

Aerojet Rocketdyne; Blue Origin

nounced in September that it would partner with Blue Origin to complete the BE-4's development. The BE-4 would power a soon-to-be-unveiled update of the Atlas 5.

"We have a complete vision of where this launch vehicle ends up, starting with the American engine replacing [the engine in] the first stage and a whole set of trades [or studies] just now finishing on what that new launch system will look like," said Tory Bruno, ULA's president and chief executive officer, who spoke at an Atlantic Council event in November.

Bruno said it typically takes about seven years to develop a rocket engine, and Blue Origin has already been at work for about three years on the BE-4. That work includes testing the pilot-light-like preburner and the propellant-mixing injector. In addition, Blue Origin built an engine test stand in West Texas, where full engine testing is scheduled to begin in 2016.

"Large engine test facilities cannot be done quickly," Blue Origin founder Jeff Bezos said at a press conference with Bruno in September. "There's just a lot of pouring of concrete and waiting for it to dry. They're big."

ULA and Blue Origin contend that liquefied natural gas, which would fuel the BE-4, is easier to use than kerosene. Engines fueled with LNG do not require tank pressurization systems, which typically use helium, a gas that "is in increasingly scarce supply," Blue Origin says in BE-4 marketing materials. LNG would also make it easier to reuse the engine, the company says. Aerojet Rocketdyne says the kerosene-fueled AR1 would benefit from knowledge the company is gaining from two government-sponsored efforts: NASA's Advanced Booster Engineering Demonstration and/or Risk Reduction program, or ABEDRR, and the Air Force's Hydrocarbon Boost Technology Demonstrator program, or HBTD.

Under ABEDRR, Aerojet Rocketdyne, Dynetics and NASA's Marshall Space Flight Center are exploring options for advanced boosters for NASA's deep-space Space Launch System rocket. Dynetics manufactured a full-scale tank that contains liquid oxygen used to feed a booster's main engines. Dynetics said it plans to test the tank this summer at its test site in Iuka, Mississippi.

The ABEDRR team also test-fired a refurbished gas generator from an Apollo-era Saturn 5 F-1 rocket engine. The gas generator drives the F-1's turbopump. Data collected from the testing were used to design and build a new gas generator injector that will undergo hot-fire testing at Marshall this year.

SpaceX

The SpaceX Falcon 9 rocket is powered by nine of the company's Merlin 1D engines, each producing 147,000 pounds of thrust at liftoff. The Falcon 9 could be certified to compete with the Atlas 5 for national security launches this year, the Air Force said.

Under the HBTD program, Aerojet Rocketdyne is working with the Air Force Research Laboratory to design and test a liquid oxygen/kerosene engine that could be used up to 100 times.

The company also says the AR1, which uses the same fuel as the RD-180, would require minimal changes to the Atlas 5 and the rocket's ground support equipment and launch infrastructure.

While SpaceX and Orbital ATK both declined to comment for this story, Air Force officials said SpaceX's Falcon 9 rocket could be certified to compete with Atlas 5 by mid-year. Ostrove says an Orbital ATK

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solid-fuel engine would provide more thrust and a smoother flight performance than a similarly sized liquid-fuel engine. It would also require less ground and launch infrastructure because it would be more stable than a liquid-fuel engine.

"However, liquid-fuel motors offer variable thrust and can be restarted," Ostrove says. "These characteristics can be valuable for launching payloads into a variety of orbits."

February. But he added that the service will have to "husband our resources" by moving some Atlas 5 missions to other rockets, such as ULA's larger Delta 4, and to new entrants, such as SpaceX's Falcon 9.

"We're looking at all the capabilities that are out there to maximize the use of the RD-180s that we have already under our control," Whelan said.

Navy Adm. Cecil Haney, head of U.S. Strategic Command, said he is confident

United Launch Alliance has about a two-year stockpile of RD-180 first-stage engines for Atlas 5 launches.

ULA

Unknowns persist

A key question is whether the Air Force and ULA can keep the Atlas 5 flying until new engines become available.

The 2015 defense authorization act bars the Air Force from buying more RD-180s. Furthermore, a panel of experts led by retired Air Force Maj. Gen. Howard J. "Mitch" Mitchell reported last spring that the United States had only 16 RD-180s stockpiled despite having 38 Atlas 5 missions on its launch manifest through fiscal 2020. Even so, the Air Force has "sufficient RD-180s to support our mission," Maj. Gen. Martin Whelan, space operations director for the Air Force deputy chief of staff for operations, plans and requirements, said at the Air Force space budget briefing in

new engines can be developed and fielded before the RD-180 supply runs out.

'We're always concerned as we transition to a new capability, but I think we have a good plan," Haney said in February at a Capitol Hill seminar on space operations. "We have to work our way through that just as we've done through so many different, various requirements with exquisite technology."

But even space industry leaders acknowledge that the Air Force has a difficult job ahead of it.

"There is no way to rush a rocket development process," Bezos said. "You can't cut corners. It needs to be methodical and deliberate."