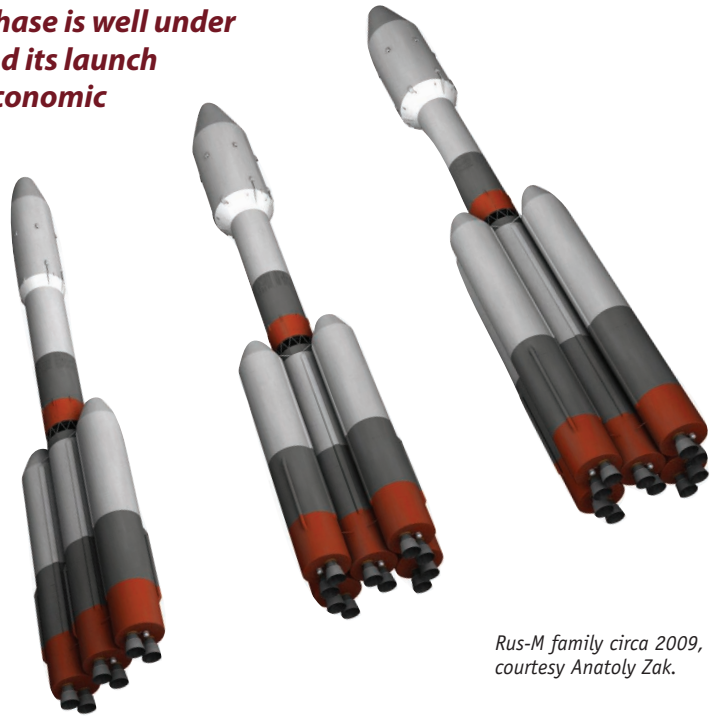
Russia's next-generation crew-carrying space vehicle, the Rus-M, will have a wide range of capabilities and built-in adaptability to multiple roles. The design phase is well under way, but ambitious plans for the booster and its launch facilities face mounting challenges. From economic turmoil to technical glitches to workforce shortages, harsh realities will make achieving the vision an uphill battle.

Perspectives on the Rus-M booster project



Rus-M family circa 2009, courtesy Anatoly Zak.

Official Russian plans for the transition of human spaceflight to a new-generation spacecraft, launch vehicle, and launch site have been well publicized, with extensive details released during the past year. The replacement for the venerable Soyuz will be a 12-ton, six-person capsule with mission capabilities ranging from space station crew transport (with one-year on-orbit stay time) to lunar access and return.

The new carrier for human crews will be the Rus-M, a modular vehicle using new airframes with existing rocket engines. It will also feature the first Russian use of liquid hydrogen fuel for human spaceflight. The new launch site, a cosmodrome to be called Vostichniy ('Eastern'), will be built from scratch near the far eastern Pacific coast of Siberia.

Promises and problems

President Dmitry Medvedev and Prime Minister Vladimir Putin are among the top government officials who have promised that the three parallel developments will reach initial operational capability by 2018.

However, Russia's recent track record on meeting booster development schedules has not been encouraging. The much-touted Angara family of launch vehicles was expected to begin flight tests this year, but these have now been delayed into 2013-2014. A prototype first stage sold to South Korea for its own satellite launch vehicle failed on its second flight (the Russians blame the South Korean upper stage). The Soyuz launch pad at Kourou, French Guyana, was to have begun operational launches last year but has suffered repeated delays. These have led to cancellation of all the originally slated payloads, and first flight is now forecast for this fall.

In addition, development of the new-generation Bulava submarine-launched ICBM, a top-priority project supervised by Russia's Roskosmos space agency, until recently has been bedeviled by substandard components from key factories. The introduction last December of an upgraded Block D3 fourth stage for the venerable Proton booster was made with inadequate ground processing documentation and practices; this led to an accidental overloading of the propellant that resulted in dumping the too-heavy stage into the Pacific Ocean north of Hawaii.

Each of these setbacks can be officially blamed on inadequate funding, a problem that allegedly has been remedied. But

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Zenit rockets are manufactured primarily in Ukraine.

space industry observers in Moscow have voiced concern that even with enough money, the rocket enterprises cannot hire enough skilled new employees to staff up for the increased efforts. Another widely acknowledged impediment to upgrades is the declining skill base of the Russian space and missile industry: More and more components, and in some cases even entire avionics and propulsion assemblies, must be purchased from foreign suppliers.

Meanwhile, the totally new Rus-M has been officially justified on the basis of the inadequacy of any further modifications to existing booster families, whatever their reliability or fabrication economy has turned out to be. Soyuz upgrades that preserve the classic frame have been marginal, but more are still under way for commercial payloads. The Proton has proven ecologically unsuitable because of the hypergolic fuels associated with its original mission as a super-ICBM. The Zenit is powerful enough, but it is manufactured mainly in Ukraine. Angara is a small to medium-weight family focused on military payloads, and heavy-lift proposals suffer from the program's inability to actually deliver even the smaller versions for flight.

One factor may prove crucial to the future of the Rus-M booster family and the space projects that will depend on it: the decades of experience Russian rocket manufactrers have had with upgrading and enhancing these rockets, which were originally built for military missions and then converted to spacelift. The Rus-M design, in contrast, has been chosen from the beginning not only to be useful in its first implementation but also to be readily adapted to much more powerful clustered variants. To an even greater degree than the modular Angara family, the Rus-M is to benefit from standardized ground processing interfaces in practically any upgraded configuration.

Test flights of the Angara family of small to medium-weight launch vehicles have been delayed into 2013-2014.

A closer look

After a two-year review, Roskosmos has settled on a Rus-M design that is also strong on classic components and familiar players. The Progress Plant will be responsible for the overall booster development. Located in Samara on the Volga River, the plant currently fabricates Soyuz boosters. It will also build the Rus-M's second stage, which will use four RD-0146 engines originally developed in the 1990s by the Khimavtomatika Bureau at Voronezh. Made for the upper stages of the Proton and Angara but never used, the RD-0146 was based on the Pratt & Whitney Rocketdyne RL10 engine originally built for Saturn and Centaur boosters more than 40 years ago.

The Makeyev Bureau at Miass will build the new rocket's first stage. The facility has built liquid-fueled submarine-launched missiles for almost 50 years but recently has undergone severe economic hardship. The first stage will use a core and two strap-ons with a total thrust of 916,500 kgf (almost twice that of the Soyuz); each booster module is limited to a diameter of 3.8 m, the size that can be transported by rail from factory to launch site. The engine selected is the kerosene-burning RD-180, now built by Energomash in Moscow for export sales to the U.S., which uses it in the Atlas-III. Rus-M will need a modified engine called the RD-180V with added diagnostic sensors for abort detection.

Rus-M will be the first Russian space booster specifically designed for human spaceflight. The baseline design reference mission is to carry a 23.8-metric-ton payload (three times the mass of the current Soyuz) into a 200-km orbit inclined 51.7 deg. Early this year, press reports stated that the payload was 1,660 kg overweight, and a design scrub was under way.

On March 31, Gennadiy Raykunov, general director of TsNIIMash (Central Machine-Building Research Institute), which provides safety and quality reviews of Russian spacecraft, reported that the vehicle was halfway through its design process. "Design and detail documentation is being drafted, integrated experimental method programs are being compiled," he told an Interfax reporter. "At least, following this stage, the paperwork will end and the hardware, tests, and development will begin," he said.

"Optimization in terms of the engines and the control system continues, operating procedures go on until there are no kinks," Raykunov added.

A number of stringent safety measures have been designed in from the start. For example, prelaunch processing would be entirely automated or teleoperated. The design also requires single-engine-out capability from liftoff, to reach an abort zone over the Pacific. From late in first-stage ascent, the booster must provide an abort-to-orbit capability. Ascent *g*-forces shall not exceed 4.0.

Detailed design work on launch support structures will allow facilities to handle

the Rus-M and all planned upgrades with minimal modifications. With a five-module combination first stage, the upgraded booster will be able to carry 60 tons into LEO. A mission architecture for a dual launch and rendezvous in lunar orbit could support an Apollo-class manned lunar landing. A single-launch vehicle with a 100-ton payload has also been designed, but it would require significant new engine work.

Other activities

The Progress Plant is also busy modifying the standard Soyuz launch vehicle for flight from French Guyana. In addition, the facility is conducting an upgrade using all-Russian guidance avionics for the Soyuz-2-1a, slated to be introduced as a carrier for the manned Soyuz spacecraft in about 2014. In direct competition with the supposedly 'universal' Angara family, the firm is also developing a 'Soyuz light' booster with the four strap-ons removed and an NK-33 engine installed in the core stage, to carry a 2,800-kg payload into a 200-km orbit.

The Moscow-based Khrunichev firm, which now manufactures Proton boosters and is responsible for developing the Angara series, also bid on the Rus-M project but received no contracts. Nevertheless it remains busy fabricating profitable Proton rockets, and in April explicitly posted those plans on its Web site: "The Proton-M will continue forming the core of Russia's federal space program in the category of heavy launch vehicles for the next decade," it wrote. This was in direct defiance of a quotation attributed to Roskosmos chief Anatoliy Perminov stating that if the first Angara launch is successful, "Proton rockets could start to be taken out of service gradually."

Khrunichev is also overseeing the complex transfer of Angara engine production and rocket body fabrication to two newly acquired subsidiaries in Perm and Omsk that formerly made smaller military missiles and launch vehicles. And it is developing plans for a pair of Angara pads at Vostochniy and another at Baikonur.

The bigger picture

Assembling the industrial team that will produce the Rus-M took place against the backdrop of an ongoing government effort to streamline and optimize the disparate elements of the Russian rocket/space industry. Many entities vanished entirely following the collapse of the USSR and its mandated subservience to central planning agencies. Others significantly shifted their industrial production, terminating fabrication of key spacecraft-related components.

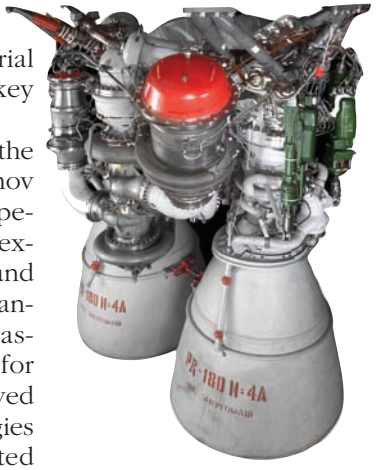
In a harsh assessment February 7 in the weekly *Nasha Versiya*, Aleksandr Stepanov wrote, "According to assessments of specialists, the Russian space industry has exhausted its scientific-technical resource and has lost the capability to develop and manufacture most of the instruments and assemblies. Extending the service life for those remaining in space today is achieved largely by bringing in foreign technologies and assemblies, and even the vaunted GLONASS satellites are being assembled with foreign parts for the most part."

Roskosmos deputy head Sergei Ponomaryov confirmed that information last March when he told Interfax that electronic components installed on Russian spacecraft have been increasingly foreign made in recent years. "The proportion of those electronic components is between 27% and 46%, depending on the type of the vehicle," Ponomaryov told a roundtable at the Russian Academy of Sciences in Moscow. Yuriy Solomonov, chief designer of the Bulava missile, concurred. In an April 20 interview, he lamented, "Hundreds of unique technologies have been lost. Many components are purchased overseas. Their manufacture here is now impossible."

No booster is useful without a launch site, and the fact that the new Rus-M booster is to fly from a site whose construction has not even started yet is another schedule threat. As of mid-2011, 24.5 billion rubles have been allocated for construction through 2013, but aside from some road signs, a stone obelisk, and a small visitors' pavilion for VIPs, nothing has been built.

Speaking to newsmen in Moscow on January 31, Perminov had described what would be built first: "A 4.5-km railroad line, a road from the Amur federal highway, and a construction depot will be ready this year," along with repair work on old power lines, he said. Housing for workers, a hotel for visitors, and a headquarters for management staff will also be built before any work begins on launch pads and processing facilities.

Perminov elaborated a month later: "Construction works will begin in June," he told an interviewer on Ekho Moskvi radio. "First and foremost, we will build roads, railroad tracks, energy and auxiliary facilities," he said. Mission support construction will require another 57 billion rubles in



A modified RD-180 engine will serve as the first stage booster for the Rus-M family.

2014, he added. But as June came and went there were no news reports of construction commencing.

Top Moscow political leaders have put their personal prestige behind the project. In January, Putin called the construction of the cosmodrome "a new big nationwide project," adding, "This will be a national cosmodrome meeting the highest international standards and capable of dealing with the whole range of space exploration tasks....[It] will guarantee Russia fully independent space activities, including the launch of all types of spacecraft, transport and cargo vehicles, modules, and orbital stations," Putin continued. He expects the site to be used for human flights to the Moon and Mars in the future, he said.

If activated, the base and the Rus-M booster will rapidly change the distribution of space traffic in Russia. Up until 2015, 64% of Russia's satellite launches have been from Baikonur, 30% from Plesetsk, and 6% from lesser cosmodromes. By 2020 that distribution is supposed to shift to 45% from Vostochniy, 44% from Plesetsk, and 11% from Baikonur.

Construction is ongoing for the Soyuz launches in French Guiana. Photographer: Aleksey Yakunin.

Doubts and objections

Inside Russia there are some who doubt that these vaulting ambitions can be realized, even if most of the promised funding is delivered (always a big 'if'). Even some of the Rus-M industrial team members have expressed reservations at being drafted into the grandiose project and consolidated into a larger space industry combine. Among them is the Energomash Research and Production Association, which is tasked to build the rocket engines for the first stage of the Rus-M.

Dmitriy Pakhomov, general director of Energomash, went public in June 2010 with his objections to becoming a branch of a 'Russian Space Corporation' based on the Energiya space facility in Moscow. He saw it as an immediate threat to seize his firm's rocket sales profits for the relief of other firms that were deeply in debt. In an interview, he pointed specifically to the demand that Energomash reduce the price of the RD-171 engine used in the Sea Launch program, to help that company—now wholly owned by Energiya—work its way out of bankruptcy. To help reduce Energiya's indebtedness over Sea Launch, Pakhomov complained, his company was supposed to lower its own profit margin.

"It is impossible to count on a positive outcome here," he noted. The vertical integration being implemented would steer all Energomash efforts to serving the engine needs of only a single rocket builder. "I have no doubts this will be done at the expense of limiting the possibilities for development of new models of engines that are required for the projects of other rocket engineering corporations, which are rivals of Energiya or can become rivals in the future," he explained, adding: "The research and design schools will be destroyed."

But Pakhomov's lack of enthusiasm counted for nothing, and his company—with or without him at the top—is firmly inserted into the project.

Bitter nostalgia

A more scholarly, independent skepticism comes from Konstantin Bogdanov, a respected specialist in the history of science. Now teaching in Germany, he wrote an essay for *Novosti* in April on the 50th anniversary of Yuri Gagarin's historic spaceflight. Bogdanov called his essay "Fallen giant: The Soviet space industry" and suggested it would never be able to revive past glories like those being nostalgically celebrated during the anniversary festivities.

"Its capacity for working miracles disappeared in the 1990s when the colossal monolith crumbled along with the system that had spawned it, leaving a sea of bitterness and grudges in its wake, as well as nostalgia for a lost paradise for engineers and technicians. The fall of the aerospace industry was cruelly sobering after several decades of intoxication with the limitless possibilities afforded under the Soviet space program.

"The seeds of the Soviet space industry's tragic downfall had been sown in its very creation," wrote Bogdanov. "It could not have been otherwise. Without those fatal flaws it would have never emerged, and would have failed to accomplish all those stunning feats that won respect [the] world over."

Time will tell if the Russian space program retains the talent and the governmental support to surmount this chosen new challenge, the greatest it has faced in 50 years. Dedication and history they clearly have in abundance, along with an inspirational motto that got them through the dark days of privation immediately after the USSR's collapse: "The difficulties ahead of us are less than those we have already overcome," workers told each other then. But is that enough?