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GETTING ITS SPACE MOJO BACK

After the Cold War, Russia emerged as a force to be reckoned with in the commercial space launch arena. Its rockets were relatively inexpensive and famously reliable. More lately, Russia has been beset by launch failures, economic woes and scandals on top of growing competition from long-standing rival Arianespace and newcomer SpaceX. Russia set out to make 2016 a turning point year. Space journalist Anatoly Zak analyzes Russia's strategy.

Russia announced an ambitious rocket modernization strategy at the start of 2016 with some unusual public reflection from its top space leaders. The occasion was the Korolev Readings, an annual gathering of Russian space strategists in Moscow named for the late Sergei Korolev, the founder of the Russian space program. Igor Komarov, the head of Roscosmos, the state-run corporation that is in charge of matters of space, cited a "considerable lag in the use of modern development methods, low productivity and worn machinery," according to my translation of his remarks. He said "modern management systems are still in the process of implementation," and he criticized what he called duplication within the industrial infrastructure. In April, Komarov doubled down, promising to direct 30 billion rubles ($482 million) of the industry's profits into modernization.

Russian Ministry of Defense

An Angara-5 lifts off from Plesetsk, Russia, in 2014 for the first flight of this Russian rocket.

The modernization strategy marks Russia's attempt to keep pace with its international competitors who are adjusting their offerings and embracing technologies such as reusability and additive manufacturing. The Russian strategy is outlined in the latest Federal Space Program, known as FKP-2025, which sets key goals, timelines and budget estimates for all civilian space-related activities in the nation from 2016 to 2025.

Implementing the new strategy will mean conducting the first paid flights of the Angara rocket series that will replace today's faltering Protons; establishing a manufacturing base for Angara production in the Siberian city of Omsk; and expanding a launch site in Vostochny in the Russian Far East to accomodate Angara. Beyond that, today's array of rockets must be consolidated into two families: the Soyuz and the Angara, with six variants of the two rockets to continue flying instead of 12. Komarov outlined the consolidation plan during the cabinet approval hearing for the FKP-2025 program, according to a government transcript.

Quality control

The first order of business for Roscosmos will be to bring its manufacturing house in order after a string of 12 Proton and seven Soyuz rocket launches since 2001 that did not go as planned, with at least two of them failures that suggested quality control issues. In 2010, a Proton rocket plunged into the ocean because too much propellant was loaded onboard. In 2013, flight control sensors mistakenly installed in the upside-down position sent another Proton into a spectacular salto mortale just seconds after liftoff.

This year, besieged by failures and with its customers increasingly fleeing to competitors, Proton might set an anti-record of sorts. It is on pace to fly at most five missions by year's end, its lowest annual launch rate in a decade. Three missions had been flown by mid-October.

As a result, the Khrunichev State Research and Production Space Center, which builds Protons in Moscow, faced a severe funding shortage, requiring layoffs, salary cuts and a huge financial bailout from the Kremlin.

To address quality control problems, the industry attempted to respond with a multiprong approach. "We are doing everything possible to minimize the influence of the human factor on the production process," Andrey Kalinovsky, the head of Khrunichev, told the Izvestia daily in July. "That is, we are implementing modern measurement diagnostic systems, which register results automatically … . By the end of the year, we plan that around 75 percent of all operations at the Proton's final assembly line will be computer controlled."

In August, Roscosmos initiated a three-year program with a 1.9-billion ruble ($30.5 million) price tag aimed at upgrading its propulsion systems. The effort includes identifying replacement materials and components for rocket engines, new measures to ensure flawless operation of propulsion systems,

new failure diagnostics, and improvements in production and quality control.

Across the industry, its leaders promised a multitude of measures to improve overall efficiency of the work, to retain the workforce, and to invest in new machinery and computerization. Amazingly, only in the past couple of years have major Russian rocket developers come around to digitizing the design process, and this effort is still ongoing.

Last year, Prime Minister Dmitry Medvedev signed a decree creating a monitoring center for personnel training within the defense industry, including its atomic and rocket sectors. Among the ideas proposed in the Russian Duma or parliament was to free young qualified employees entering the defense industry from the compulsory military service.

Proton might set an anti-record of sorts, flying only five missions during 2016, its lowest annual launch rate in a decade.

PLANNING

Long-range planning: Every 10 years, Russia approves an updated space strategy outlining key goals, timelines and budget estimates. The latest strategy, called FKP-2025, short for Federal Space Program, was approved in March and spans from 2016 through 2025.

Roscosmos also created a directorate specifically for quality and reliability, although the situation might already have been improving. In May, Vladimir Evdokimov, the executive director for quality and reliability at Roscosmos, said defects across the industry have been reduced by 21 percent over the last two years. With just weeks left in 2016, Russia has not had any launch failures, compared to three failed launches in 2015 and three more in 2014.

Adapting for smaller payloads

On the engineering front, Khrunichev looked at various low-cost options for adjusting its fleet to carry a wider range of payloads. For Proton, that means not only increasing payload capacity, but also scaling down the rocket for lighter cargo. Kalinovsky, the Khrunichev chief, announced plans for a new addition to the Proton family, known as Proton-Light, to deliver smaller commercial spacecraft.

In its new configuration, Proton-Light could fill the gap in the payload range between 3.5 and 5 tons delivered to the geostationary orbit popular for commercial communications satellites. This gap in lifting capacity of the Russian space fleet was left by the absence of Zenit rockets, which are made in Ukraine and are no longer available to Russia following its annexation of Crimea in 2014. The lighter, cheaper Proton variant will exactly overlap the capabilities of the American Falcon-9 rocket, putting it in direct competition with SpaceX.

Kalinovsky told the Tass news agency that he had hoped to have Proton-Light ready for launch as early as 2018. According to Khrunichev, the company aims to reduce the cost of making the Proton rocket to 1.38 billion rubles ($22.2 million) apiece, in part, by winning enough commercial orders for up to seven launches per year. If that reduction is achieved, it would likely give Russia a significant competitive edge on the international market.

Troubled generation

The Proton upgrades are seen as stopgap measures before this Cold War-era, toxin-emitting behemoth is replaced with the Angaras. Protons burn dimethylhydrazine fuel with nitrogen tetroxide oxidizer, chemicals that are dangerous for workers and the environment. These components have been largely phased out by the world's other major space launch providers in favor of kerosene or liquid hydrogen fuel and liquid oxygen oxidizer. According to the strategy Russia set in the 1990s, the Proton rocket along with its launch pads based in the former Soviet republic of Kazakhstan were to have been retired by now in favor of Angaras launched from Russian territory. The Angara, burning nontoxic kerosene fuel, was also designed around a modular architecture, enabling the use of common booster stages in at least three different configurations with their own mass categories. The largest, five-booster variant, could match Proton, or so Angara's developers hoped.

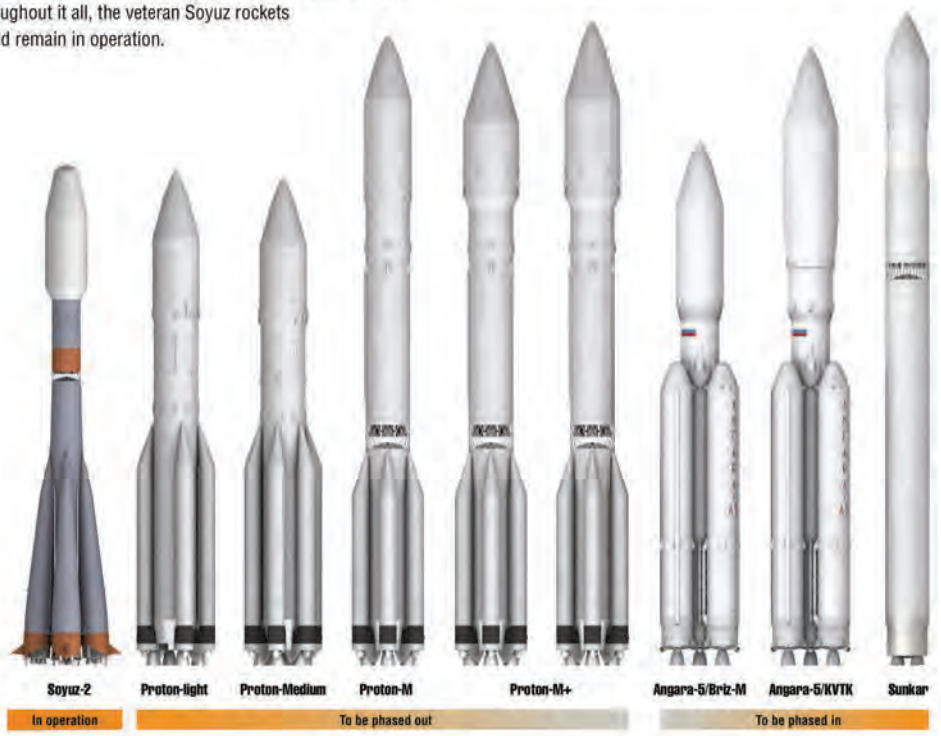
Like many other things in Russian history, the Angara's path toward the market has not been straightforward or easy. In 2014, after a decade of delays, the light and heavy versions of the Angara rockets performed as planned in test flights, but two years later, the new shiny booster is still years away from being able to replace Proton. The development work was complicated by the simultaneous effort to shift the rocket production from Moscow to Omsk to reduce the manufacturing cost and match the rock-bottom price of the Proton. To achieve that, the Siberian factory needs to operate 24/7 in three shifts to churn out up to 100 Angara boosters per year by 2021.

The silver lining for this monumental transition is the creation of the first state-of-the-art rocket facility of the post-Soviet era. "Trust me, from the point of view of production organization and its philosophy, our company will be one of the most advanced," Kalinovsky told the official RIA Novosti news agency in June.

The Angara has a possible Achilles' Heel, namely the rocket's launch pad in Plesetsk. Built according to the 1990s requirements of the Russian military, the near-polar-circle facility is ill-suited for a competitive commercial race to the equatorial orbit. To fix the problem, Roscosmos now plans to expand

Russian rockets circa 2025

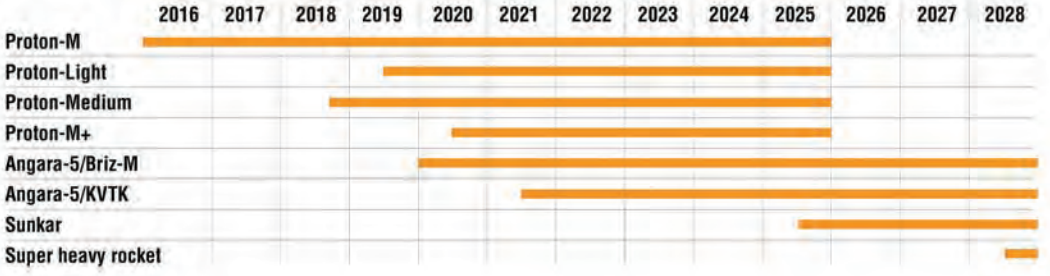
The Roscosmos State Corporation plans to replace its workhorse Proton rockets, burning toxic propellants and based in neighboring Kazakhstan, with a new Angara series relying on environmentally neutral fuel and based at a launch site in Vostochny in Russia's Far East. Simultaneously, a new type of booster, dubbed Sunkar, might reach the launch pad, replacing the Ukrainian-built Zenit and paving the way for super heavy rocket later in the 2020s. Throughout it all, the veteran Soyuz rockets would remain in operation.



	Soyuz-2	Proton-M Phase 4	Angara-5/Briz-M	Sunkar
Liftoff mass	312 tons	~705 tons	773 tons	520 tons
Payload to Low Earth Orbit	8.2 tons	22 tons	24.5 tons	17 tons
Payload to Geostationary Transfer Orbit	3.06 tons*	6.35 tons	5.4 tons**	5.0 tons

*from Europe's Spaceport in Kourou, French Guiana; ** from Plesetsk Cosmodrome in Russia

Approximate operational timeline



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the new Vostochny spaceport in the country's Far East to launch Angara vehicles. With the evergreen taiga hardly cleared around the future launch pad, the facility is not expected to enter operations until the early 2020s. In the meantime, expect Proton to continue flying until at least the mid-2020s. Recent economic problems in Russia put more hurdles before the project, raising serious questions about the realistic completion date for the Angara's commercial launch pad.

Will Phoenix rise?

Even with Angara progressing, Russian rocketeers have little time to rest. One of the criticisms leveled against the Angara is that its modular boosters were sized too small during the economically difficult mid-1990s, severely limiting its growth potential in terms of payload.

Now, Roscosmos feels it is time to address that problem, as well, with the project dubbed Feniks, pronounced like Phoenix. The original goal was to

Russian Ministry of Defense

▲ **Russia's first** Angara-5 rocket undergoes pre-launch processing in Plesetsk, Russia. The Angaras will burn nontoxic kerosene fuel, making them an attractive successor to the country's Protons.

build a rocket that would burn cryogenic methane fuel and replace the historic Soyuz boosters. After several course corrections, Russia this year began steering toward development of Feniks as a Zenit rocket on steroids. Generally resembling its Ukrainian predecessor, the Russian version will have a slightly larger diameter of 4.1 meters, which is the maximum for transporting the oversized first stage along the Russian rail network to the launch site at Baikonur in Kazakhstan. Also, that diameter had already been adopted for the Proton, so, theoretically, the same tooling and machinery could be used to make the new rocket, greatly cutting the development time and reducing the cost of the overall project.

The first stage of the Feniks will be propelled by the RD-171 engine inherited from the Zenit, giving a new job to the world's most powerful rocket motor, despite Russia's annexation of Crimea. Moscow-based NPO Energomash still produces a half-size version of the same engine dubbed RD-180 for the American Atlas and a quarter size designated RD-191 for the Angara.

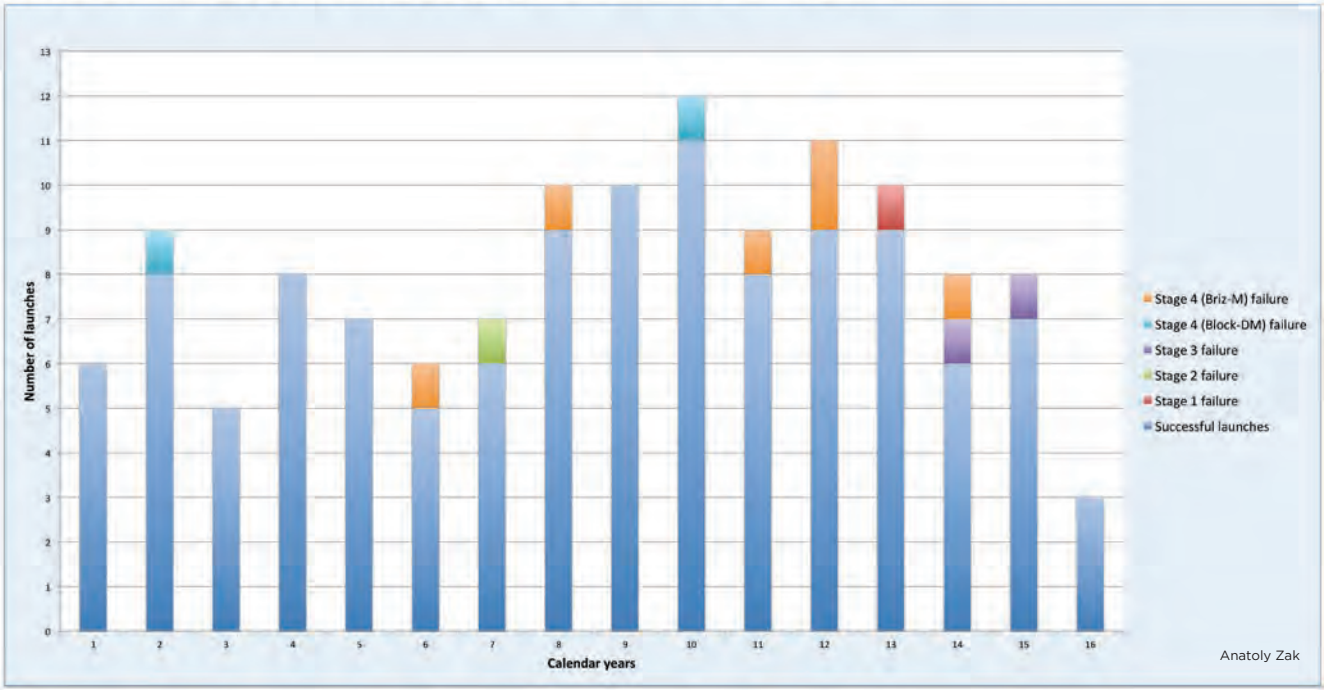
The second stage on the Feniks will be propelled by a pair of RD-0124A engines borrowed from the Angara.

The Feniks launcher could reach the launch pad around 2024 (right about the time of the Proton's expected retirement) and deliver an estimated 17 tons to the low-Earth orbit and around 2.5 tons to the geostationary orbit.

To improve chances for Feniks' success, Russia resumed talks with Kazakhstan on the long-stalled Baiterek project. Its original goal set in 2004 was to deploy a commercial version of the Angara rocket at the Kazakh-paid launch pad in Baikonur. However, the idea withered, apparently after Kazakh landlords had gotten a price quote for the future facility from Russian contractors. Now, the strategy evolved to put jointly funded Feniks-based rockets at the unused Zenit pad in Baikonur. Specifically for the joint Russian–Kazakh venture, the future rocket was dubbed Sunkar. It is positioned to fill the market niche that would be initially served by the Pro-

Proton launch numbers through the years

Russia has launched 129 Protons since 2001, with just three launches so far this year compared with a peak of 12 in 2010. Twelve of the launches have experienced varying levels of failure, with eight of those failures occurring since 2010. The launch rate by year and type of failure:



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ton-Light vehicle before it retires.

Not coincidentally, Russian strategists believe that the market segment of medium-sized satellites requiring Proton-Light, and later Sunkar-Feniks, will see sizable growth in the coming years. They expect almost flat orders among heavier satellites and a drop in sales predicted for smaller satellites. Roscosmos officials are banking on the emerging use of electric engines on commercial satellites to lighten them into the medium category, because they will not carry the traditional liquid-propellant thrusters.

Back to super booster

In addition to its commercial role, the Feniks booster could become a stepping stone toward a super rocket approaching the capabilities of NASA's Space Launch System booster now in development. Angara's standard rocket modules would never be able to provide that kind of capacity.

The yet-to-be approved, let alone funded, Russian super rocket would be linked to the future of Russian human spaceflight. Because the Kremlin sees the moon as the main strategic destination for its cosmonauts, several attempts have been made in recent years to devise a lunar-exploration strategy not reliant on giant rockets. One idea called for pushing the Angara to its absolute limit with hydrogen-powered upper stages to deliver payloads to the moon. Speaking at the International Astronautical Congress in 2015, Vladimir Solntsev, the head of RKK Energia, Russia's main human spaceflight contractor, said that a lunar expedition based on four Angara-5V rockets could have four times cheaper costs than a similar mission launched by a single SLS rocket.

However, this year's calculations made at RKK Energia showed that these plans would be too risky for a trip to the moon. Splitting the mission into four launches would bring down the probability of its success to 67 percent compared with 90 percent when sending cosmonauts to the moon with the help of only two larger rockets.

As a result, Roscosmos reportedly dropped plans to develop a hydrogen-powered booster for the Angara-5V rocket and will switch any possible lunar expeditions to a super-heavy vehicle similar to the SLS. The latest Russian concept of this giant rocket calls for clustering together up to seven Feniks boosters. "I am sure we can develop the super heavy rocket under this scheme in a record time — we are talking five, seven years," Solntsev told Izvestia in August.

Russian officials optimistically hope that the rocket capable of delivering 80 tons into orbit could be ready for flight around 2025, or just a few years after a new-generation spacecraft designed to carry cosmonauts to the moon is expected to come online. Further upgrades of the rocket could boost its payload to 120 or even 160 tons.

Whether Roscosmos manages to carry out FKP-2025 will depend heavily on the state of the Russian economy, which relies on oil prices and trade relations with the outside world. Those factors will decide the actual budget that Roscosmos will receive and they are beyond the space industry's control. What it can control is attaining success in its new strategy of reforming the industry and modernizing the nation's space fleet.

Those factors will ultimately determine success and that's why 2016 could go down as a turning point year for the Russian space enterprise. ★

Roscosmos

▲ **A Russian** Proton is erected on the launch pad at Baikonur Cosmodrome in Kazakhstan. Proton launches have declined sharply in recent years but Russian officials have plans to reverse the slide with a new version, called Proton-Light.

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grew up in Moscow and publishes the RussianSpaceWeb.com news site from New Jersey.