SPACE SCIENCE

Trying to Continue Research On a Wing and a Prayer

MOSCOW—In the true spirit of aviation's pioneers, Russia's space scientists are, in a sense, flying by the seats of their pants. Their country still maintains a crewed space station and carries out more launches each year than the rest of the world put together. But this huge program—and the impressive array of science projects it supports—owed its existence largely to the Soviet military's interest in space. Now that the Cold War is over, Russia's bloated military-industrial complex no longer has unlimited funds to lavish on the space program. And with the country lurching ever deeper into economic chaos, the future of Russian space science is hanging in the balance.

At the nerve center of Russia's space science program, the Institute of Space Research (IKI) in Moscow, collaboration and cost-sharing with Western agencies have emerged as the keys to survival: All of the major space science missions due for launch in the next few years include significant Western involvement. And with continued support from the Russian government seemingly contingent on heavy collaboration with the West, IKI staff members are struggling desperately to keep these projects on schedule. Indeed, if IKI's international projects are lost or get badly delayed, the institute's very existence is in doubt. "We don't know what tomorrow brings," says Alexander Zakharov, IKI's scientific secretary. "It is important to continue and launch as soon as possible. Anything can happen."

That struggle to keep missions on track was dealt a serious blow at the end of last month when IKI was forced to postpone its largest current mission, Mars 94, for 2 years after numerous delays made it impossible to meet its launch window this October. The delay in this ambitious mission, comprising an orbiter and several surface probes, is a major setback for planetary scientists in both the East and the West still smarting from the loss of the U.S. National Aeronautics and Space Administration (NASA)'s Mars Observer last August. "It's disappointing," says Barbara Brown, Mars 94 project manager at NASA's Jet Propulsion Laboratory in Pasadena, California. "We wanted to keep to '94 because of the Mars Observer, but as long as there is '96, it will be OK."

This setback leaves IKI with just one major mission per year for the next few years. Interball, a group of four satellites still slated for launch this fall, will study the interaction between the sun and the Earth's atmosphere and magnetosphere; and in 1995 there will be Spectrum-X-Gamma, a multi-telescope orbiting observatory that will focus on the x-ray and gamma-ray regions of the spectrum. "The current program is the minimum program to maintain space science in Russia. There is nothing left to drop," says Albert Galeev, IKI's director-general.

Dreaming of the red planet. For decades, Venus had been the main focus of interest for Soviet planetary scientists, but in the 1980s their attention shifted. The Mars 94 mission and a follow-up dubbed Mars 96 were conceived as elements of an ambitious plan hatched by IKI to explore the red planet. These two surveying missions were to be followed by a sample-return mission at around the turn of the century, and after that, the equipment necessary for human visitors would be tested in preparation for a crewed mission sometime after 2005.

Mars 96 was delayed to 1998 earlier this year, and the rest of the program has long since been abandoned. So with Mars 94 also delayed, the whole program is on the blocks. But IKI is still bullish about its prospects. "We will work for the same mission in 1996," says Vasilii Moroz, IKI's head of planetary physics. Even if it goes ahead unchanged in 2 years, it will still be an impressive mission, with contributions from 20 nations. The main part of the spacecraft is an orbiter that will map large parts of the planet's surface as well as study its climate, atmosphere, the halo of plasma above that, and its magnetic field. The craft will also dispatch two small landers loaded with atmospheric and climate sensors, seismic instruments, soil samplers, and TV cameras. Finally, two penetrators—long, thin probes that will descend, javelinlike, toward the surface and bury themselves in the rock to a depth of up to 6 meters—will send back data on the planet's geology and seismic activity.

"It's a significant mission. There's been nothing like it since Viking [NASA's twin landers and orbiters of the mid-1970s]," says Alan Johnstone of University College London's Mullard Space Science Laboratory. "For us [Mars 94] is the chance to be on the first plasma exploration of Mars," he adds.

There is a measure of dispute over who is to blame for the mission's delay. The prime suspect is the Russian government. In both 1992 and 1993, IKI received no money from the government until the late summer, making planning difficult and subcontractors unhappy. "They've had so many problems internally," says NASA's Brown. But IKI maintains that not all the problems originated in Russia. "There were many delays in the delivery of parts and instruments," says Moroz.

There were technical hold-ups too. Western participants pinpoint the ARGUS platform on the Mars 94 orbiter as the main source of problems. The platform, which carries two cameras and a spectrometer to analyze light reflected from the ground, is designed to tilt so that the instruments scan over the planet's surface. "The Russians built a sturdy platform, but the electronics are the problem," says Brown. The possibility of flying the platform fixed was considered, but the loss of the ability to scan would have made the instruments it carries virtually useless, a prospect not relished by the French and German scientists who have spent millions of dollars developing them. "It is out of our control. Whenever we suggest anything, the Russians get angry. It is very painful for us," says planetary scientist Jacques Blamont of the French space agency CNES. The delay will come as a relief to many of the international partners in the mission. Johnstone says that this year's rush to meet the deadline, and the consequent possibility of mistakes, was "doomed to failure."

IKI plans to push ahead and complete the integration of the spacecraft before the end of the year, but there are still some worries in the West about Russia's future. "I don't want to leave my hardware there," says Brown. Flying the mission in 1996 also opens up the possibility of splitting the instruments between two spacecraft so that more could be carried—IKI has a stock of spares from the engineering models used in testing. "Conflicting requirements could be resolved: The cameras and the plasma instruments need different orbits. It would solve a number of

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Grounded. Project leader Vasilii Moroz will have to wait two more years to fly his planned mission to Mars.

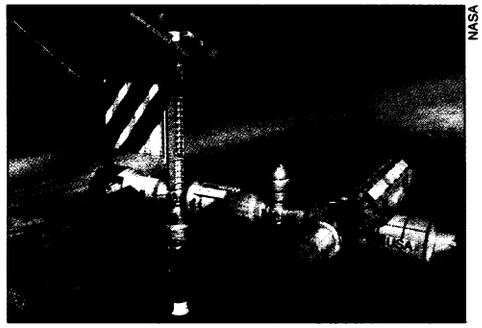
problems," says Johnstone. Launching two spacecraft also reduces the impact if one craft should fail, but money is the inevitable problem. "It would be better to have two, but it would be more expensive," says Moroz.

Despite the disappointment, Mars 94 has provided valuable lessons for both IKI and its Western partners in the art of collaboration. Wes Huntress, head of space science at NASA, says scientific exchanges between the two sides have been very beneficial, "but culturally they have a different way of doing missions, and that has sometimes been difficult." Russian work plans have softer milestones, he says. "Sometimes it is hard to understand what their schedule is." And their documentation is not as thorough as that demanded of NASA projects. "But then maybe we have too much," Huntress admits.

The experience gained in collaborating on Mars 94 has certainly helped keep IKI's main planned astrophysics mission, Spectrum-X-Gamma, on track. This project, which is due for launch in the fall of 1995, has required even closer cooperation between Russian and Western groups. Technically, the mission is going relatively smoothly. Engineering tests are now underway at IKI on models of many of its 28 instruments and its two huge telescopes. Because the West has a lead in high-technology sensors, IKI was keen to bring in foreign help with the mission. And the sheer size of the two telescopes has forced Russian and Western groups to collaborate in their construction—a departure from previous collaborations, where Western groups have simply supplied smaller packages of instrumentation to be bolted onto the spacecraft.

Space Station: A Marriage of Convenience

When the Russian and U.S. space programs tied the knot last September to work together on an international space station, it was not quite a match made in heaven, but the union does have major benefits for both sides. The U.S. National Aeronautics and Space Administration (NASA) gets a chance to learn from Russia's wealth of experience in running a space station—the current Mir station has been in orbit since 1986—and to tap into Russia's relatively inexpensive aerospace industry for cheap parts for the future station. For Russia, the union gives an international stamp to its crewed space program, a move that may help secure its future just as it is helping other space-science missions (see main text). But it is destined to be a difficult marriage.



NASA

Orbiting hybrid. Latest design incorporates Russian modules, but its future is up in the air.

The details of the deal were still being hammered out as *Science* went to press, but the outline is clear. NASA will pay $400 million over 4 years to the Russian Space Agency (RSA) to provide key hardware for the station. NASA sources say they currently expect to receive equipment known as the "Salyut tug" for guidance, navigation, and control of the station; three research modules; and an "enhanced" version of Mir's living module that will be the core of the new station.

Part of the agreement will also involve hands-on work for U.S. astronauts aboard Mir. Beginning next October, U.S. shuttles will dock nine times in 2 years with Mir so that NASA scientists can try out two new research modules—called Priroda and Spektr—that will be hooked onto Mir next year. Research aboard the two modules will give NASA officials a sense of what can be accomplished on the future station's Russian modules, says Frank Sulzman, head of research programs at NASA's Office of Life and Microgravity Sciences and Applications.

Priroda and Spektr have been in the planning stages in Russia for years. They will be uncrewed except when astronauts periodically take measurements and retrieve samples, and will be packed with 1.5 tons of scientific equipment. Priroda is Russia's answer to NASA's planned Earth Observing System satellites and will carry a battery of sensors provided by France, Germany, Britain, Russia, and the United States—including high-resolution cameras, laser radars, and spectrometers—to study environmental processes in the atmosphere and on the Earth's surface. RSA originally planned Spektr as a chemistry/physics lab to study the upper atmosphere, but the latest plan includes biomedical equipment, mostly supplied by NASA, including freezers, an echocardiograph, radiation dosimeters, and a rotating chair for studying balance in microgravity.

So far, the deal seems to have something for everyone, but many space scientists and space policy analysts still feel uneasy about Russia's shaky political climate. Particularly unnerving, say some policy analysts, is that NASA proposes to rely on an advanced version—not yet designed—of a Russian spacecraft for an occasional boost to keep the finished space station in orbit. This will mean relying on the Russians for the station's entire lifetime, says Marcia Smith, an aerospace policy analyst at the Congressional Research Service. Some members of Congress would prefer that Russia "enhance" the station rather than provide critical hardware.

Another wild card is the participation of the other partners in the space station project—the European Space Agency (ESA), Canada, and Japan—who have watched from the sidelines as their roles in the space station have been made to fit around the Russians. Earlier this year Canada, citing economic constraints, threatened to pull out; last month, however, NASA and the Canadian Space Agency agreed to reduce Canada's station costs to salvage its participation. Officials at the Japanese and European space agencies have publicly supported Russia's involvement; however, one ESA official told *Science* that Europe still has strong concerns about the station's fate if Russia were unable to deliver the goods. NASA says it's working on "contingency plans" for the station if the Russians were to pull out, maintaining to a skeptical Congress that it will still be a going concern.

The Russians may, however, have greater cause for concern about fickle U.S. politics: Support for the station in Congress this year looks weak. If Congress were to send the station the way of the Superconducting Super Collider, the Russians say they would still try to build an advanced version of Mir even if the Americans were to quit. They would probably still need foreign help, however, possibly from Germany. Such a deal would make sense because Germany and Russia have in the past collaborated on several space projects, says space policy analyst John Pike of the Federation of American Scientists.

Even though both sides say they would soldier on after a divorce, it is not clear that either partner could live without the other. A marital breakup would probably leave researchers without a permanent home in space.

–Richard Stone

The larger of the two telescopes, SODART, is 8 meters long and is being built by a Russian/Danish team; the second, JET-X, with major involvement from Britain, Germany, and Italy, is 4 meters long. Together, they will allow the most detailed studies to date on distant x-ray galaxies and quasars, candidate black holes, and the diffuse x-ray background radiation, the origin of which is still a mystery.

This unprecedentedly close East-West interaction has encountered some stumbling blocks, however. "It's a political rat's nest," says Mike Cruise of the Rutherford Appleton Laboratory in Oxfordshire, Britain's leader in Spectrum-X-Gamma. "The Russians have never run a program on these terms before, with scientific leadership coming from the West. They are used to being more autocratic." And Russian scientists have grounds for complaints of their own: Sometimes they have been denied access to the technical details of the equipment the West is providing. The United States is supplying 200 kilograms of instruments, more than for any previous Russian mission, according to Rashid Sunyaev, head of IKI's Spectrum-X-Gamma team. Yet when the engineering model of the U.S. MOXE all-sky x-ray monitor arrived in Moscow, it had holographic seals on the screws that held the box together, preventing Russian scientists from examining its contents. Sunyaev, who notes that national weapons laboratories such as Sandia and Lawrence Livermore are involved in the U.S. contribution, believes this secrecy is a relic of the Cold War. "It's strange to be collaborating with institutes that were once our main enemies," he says.

The collaboration that is guiding IKI's third major upcoming mission, Interball, does not require bringing former enemies together, but it does involve a more formal structure. The four Interball spacecraft, which include contributions from 14 countries, are among a dozen or so probes that will be launched by the world's space agencies during the 1990s to study how the solar wind—the stream of particles flying out from the sun—affects the plasma of ions held in place around the Earth by its magnetic field. The operation and data-gathering of all these solar-terrestrial physics missions is being coordinated through a body called the Inter-Agency Consultative Group for Space Science (IACG). The group, which includes NASA, the European Space Agency (ESA), IKI, and Japan's Institute of Space and Astronautical Science, was formed in 1981 to coordinate the five spacecraft launched to observe Halley's Comet's close encounter with the sun in 1986. "The IACG is our major forum for meeting the Russians. We have a good relationship," says Giacomo Cavallo of ESA's science program.

Although the number of East-West collaborations has vastly increased, it may not be enough to keep space science alive in Russia's current turmoil. IKI is pushing for even deeper collaboration with the West to use as leverage to secure Russian government support. "We are told very often that if the U.S. is interested in a particular mission, then the Russian Space Agency perks up and listens," says NASA's Brown. "Now Russia cannot do big projects alone; it costs too much money," Zakharov explains. In the future, Zakharov advocates large, truly international consortia that could exploit Russia's relatively cheap aerospace industry. "I would vote with both hands for Mars 98 to go this way," he says.


GEORGE DE KEERLE/SYGMA

X-ray vision. Jet-X, Spectrum-X-Gamma's second telescope, a new view on collaboration.

But Western collaborators are still nervous about Russia's political instability. "My job is to pull the plug on U.K. collaboration if there are problems in Russia....[E]very time there is a coup, I start sweating," says Britain's Cruise. But the desire among Western space scientists to continue collaborating with IKI is strong. "It would be easy to play a cautious card [and pull out of Spectrum-X-Gamma], but we have made a big investment, and it is a valuable scientific opportunity," says Cruise.

Indeed, many space policy experts take the view that Western space agencies would benefit from forging stronger bonds with the Russians. Says Jack Leeming, former head of the British National Space Center, who last year co-authored a report on the status of the Russian space program for the European Union: "The chaos view is quite wrong.... They are serious partners. We should help to sustain their capabilities that are useful to them and to us."

Western analysts are particularly impressed by the performance of the Russian Space Agency (RSA), a new body created in February 1992. After the disintegration of the Soviet Union, which tore apart the old Glavkosmos space agency, IKI spent more than 6 months receiving most of its funding straight from the science ministry, which was not a happy experience. "They are just bureaucrats. The money was sent but they were inflexible," says IKI director-general Galeev. RSA is proving to be a more sympathetic patron. "The space agency takes care; it gives extra money when it is needed," says Galeev. And Leeming says the space agency deserves great credit for holding the space program together in the face of considerable difficulties. "Over the last 9 months it has been evident that it is working. [RSA] has a clear policy. They are short of money, but then everyone is."

And it does appear that Western agencies are warming to collaboration with Russia on science projects: One of the options for launching ESA's planned gamma-ray observatory Integral is on board a Russian Proton launcher. "Integral will be a major collaboration," says ESA's Cavallo. Meanwhile, NASA's Huntress headed a delegation to Russia in April to discuss new collaborative projects. "We wanted to see if we could identify a small number of truly joint cooperative missions," he says. "Up to now, participation has always been as part of the other side's missions. We wanted true cooperation."

The two sides agreed to continue NASA's close involvement in Spectrum-X-Gamma and two follow-ons in the ultraviolet and radio parts of the spectrum. They also decided to look at pooling their efforts on Mars: launching probes in pairs, one Russian and one American, the first two in 1998. "It's a step towards the full internationalization of the Mars exploration program. I'm very excited about it," says Huntress.

The third mission discussed was an entirely new one, which Huntress dubs "Fire and Ice." Two similar spacecraft, principally U.S.-built and lofted on Russian Proton launchers, would be dispatched to the extremities of the solar system. One would fly by Pluto, dropping a small Russian-built probe which would gather data on the planet's atmosphere and surface until it impacts with it. The other would head for the sun, studying it at close range and also dropping a descent probe that would "keep snapping 'til it fried," says Huntress. Technical study groups on both sides will now assess the feasibility of the new proposals. In today's uncertain climate, no one knows whether any of them will fly, but Huntress thinks that a new era of truly global cooperation in space science may be beginning. "I think it was a historic meeting," he says.

–Daniel Clery