A New Soviet Plan for Exploring the Planets

Perestroika and glasnost may be rendering everything uncertain, but the Soviets haven't stopped looking outward

ONE THING ABOUT THE SOVIET planetary scientists: they haven't lost their imagination and verve. Even in the midst of political ferment, economic chaos, and a very public embarrassment—the recent failure of their Phobos mission to Mars—they continue to spin ambitious visions for the future.

Academician Valery Barsukov made that clear recently when he reviewed the latest Soviet planetary mission proposals at an international conference on solar system exploration, held at the California Institute of Technology.* His wish list ranged from balloons drifting above the canyonlands of Mars, to probes bringing home geologic samples from the asteroids, to landing craft roving the surface of Mercury.

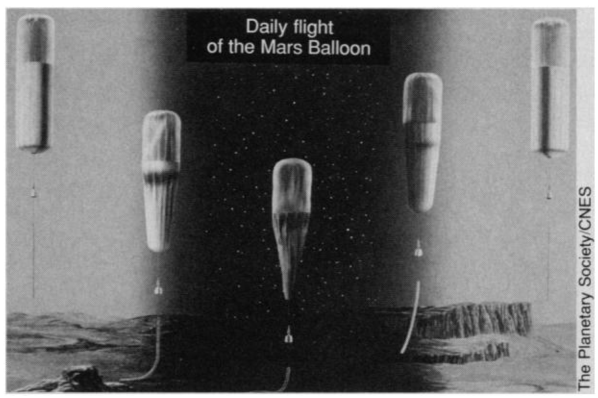
"An elaboration of our space program up to 2005," he called the plan, explaining that it was part of a perestroika-inspired effort by the Soviet Academy of Sciences and Soviet industry to reevaluate the nation's space program as a whole. Barsukov, who directs the Academy's Vernadsky Institute, a rough equivalent of the U.S. Geological Survey, is chairman of the 2005 project's planetary exploration committee.

Barsukov was the first to admit that the planetary plan he presented at Caltech could look considerably different by the time it is presented to the Soviet leadership for approval, an event that is scheduled for sometime this fall. Western scientists were likewise cautious, especially in view of the Soviet Union's many preoccupations these days. Said James Head, a Brown University geologist who has a long-standing working relationship with the Vernadsky Institute, "Barsakov's list is some combination of advanced planning and dreams."

Still, Head and other Western scientists agreed that the Barsukov's plan offered new and intriguing insights into the Soviets' thinking. Some highlights:

■ **Mars 1994.** By far the best developed of the Soviet missions, this $450-million effort involves extensive international participation, particularly from the French national space agency, CNES. Indeed, the Soviet government's formal go-ahead is widely expected in the near future.

The mission plan calls for two identical spacecraft based on the same design as the ill-fated Phobos—albeit with numerous improvements intended to prevent the computer failure that destroyed their predecessor. Launched in November 1994 and arriving in Mars orbit in October 1995, the two spacecraft would spend the next 18 months training a battery of remote sensing instruments on the Martian surface.



Touring Mars by sunpower. *Rising and falling with the sun, the Mars 94 balloons could drift thousands of kilometers.*

Soon after arrival, meanwhile, each spacecraft would release a landing package bearing a balloon, which is being developed by CNES, and a set of tiny seismic stations. During the day, as each 20-meter tall, helium-filled balloon warmed in the sun, it would rise in the thin Martian atmosphere and drift across the ancient lava flows and stream beds at an altitude of 2 to 4 kilometers. Dangling below would be a gondola carrying some 4 kilograms of instruments, the most dramatic of which should be a set of panoramic cameras. Below that would be another 4 kilograms of instruments inside a flexible tube known as the snake.

During the night, each rapidly cooling balloon would drop until the snake lay along the surface, whereupon the balloon would cease to drop and would hover all night. The instruments in the snake, which is being developed by the Planetary Society, a U.S. space advocacy group, would then gather surface data until the balloon soared again at sunrise. Meanwhile, the panoramic cameras, now hovering only meters above the surface, would be sending back high-resolution close-ups of the Martian landscape.

French and Soviet scientists estimate that each of the two Mars 94 balloons should cycle up and down like this for about 10 days before losing too much helium to rise again. A recent U.S.–Soviet cooperation agreement calls for much of the balloon data to be relayed to Earth by the U.S. Mars Observer spacecraft, which is slated for launch in 1992.

Less defined is the seismic mission. The Soviets are still looking at several concepts, though according to Soviet participants at the Caltech conference, the most likely choice is a set of about four "penetrators": spike-like probes that could be dropped directly from orbit into solid rock.

■ **"Subsatellite" for the U.S. Lunar Observer.** This is a brand new proposal for collaboration with the National Aeronautics and Space Administration. The U.S has discussed sending up a Lunar Observer mission in the mid-1990s to do mineralogical mapping of the moon. If and when the United States does so, said Barsukov, the Soviets propose to deploy a separate, smaller satellite in the same orbit to serve as a radio relay. Continuous communications would allow for much better tracking of the Lunar Observer, and therefore much better mapping of the moon's gravitational field. In return, Soviet scientists would expect to serve on the Lunar Observer mission team.

■ **A Phobos-Asteroid mission.** Also new to Western scientists, this mission would again involve two craft, using the basic Phobos design. Around 1996–1997, one would go to Mars, where it would approach the Red Planet's 22-kilometer moon Phobos and attempt to finish its predecessors' mission by sampling and analyzing the little moon's surface. It would also attempt to go its predecessor one better by returning a sample of Phobos to Earth.

At the same time, the second spacecraft would proceed to the main asteroid belt just outside the orbit of Mars, where it would sink penetrators into two large asteroids, one of them probably Vesta. The missions are linked conceptually by the fact that Phobos is thought to be an asteroid that was somehow captured by Mars.

■ **A return to Venus.** The idea here is to target interesting geological structures on

*The Second AIAA/JPL Conference on Solar System Exploration, 22 to 24 August 1989, California Institute of Technology, Pasadena, CA.

the cloud-shrouded planet using imaging radar maps from their own Venera 15 and 16 spacecraft of the early 1980s and from NASA's Magellan spacecraft, which is now en route to Venus. A Soviet mission in about 1998 would then place penetrators in eight to ten of the most promising sites, while dropping landers that could obtain panoramic views of the Venusian terrain on the way down.

■ **A Mercury lander.** Even Barsukov admitted that this mission is tentative. But Mercury's scientific appeal is clear: it is the planet closest to the sun; its surface is a unique study in the extremes of daytime heat and nighttime cold; and it is the only one of the inner planets whose surface has not been probed by a landing craft. So the Soviets would like to launch a Mercury probe just after the turn of the century.

How real was all this? No one really knows—perhaps not even the Soviets. U.S. participants at the conference noted that the Soviets' language seemed much more tentative than it had been in the past. Barsukov clearly cast his talk in terms of "Here's some things we might like to do if we have the money and political support."

In addition, Barsukov made no secret of the fact that he and his colleagues are following, not leading. In drawing up their plans they have first looked at what their Western counterparts are up to and then looked for unoccupied niches that can be filled by Soviet capabilities. As expected, for example, his planetary plan continued the Soviet focus on the inner solar system (Mercury, Venus, the moon, and Mars), leaving the distant outer solar system (Jupiter, Saturn, Uranus, Neptune, and Pluto) to U.S. and European missions; Soviet spacecraft have simply not demonstrated the longevity required to reach those planets.

Barsukov was even more explicit when he talked of a possible Mars Sample Return mission, which the Soviets had previously billed as the centerpiece of their whole planetary program, and which is widely considered to be an essential precursor for any manned Mars expedition. Today the Soviets cannot even put a date on the multibillion-dollar effort, admitted Barsukov, because they know they cannot do it without help: "We should plan for the same date as the Americans do."

Still, Barsukov also made it clear that he and his colleagues have not stopped dreaming: "In the next century," he said, "we start collaboration for manned flights to the moon . . . [as] an intermediate step to manned flights to Mars. Who knows when—the middle of the next century? It is something to leave to our children to do."

■ M. Mitchell Waldrop

An Astrophysical Guide to the Weather on Earth

A mathematical method for modeling fluid flow in outer space has down-to-earth applications as well

Supernovas, solar flares, and the nuclear brew of stars may seem pretty far removed from the earthbound world of meteorology. But a mathematical technique that was developed to model the violent processes of stellar convection and supersonic jets may now do the same for the seeming chaos of ordinary weather.

Known as the Piecewise Parabolic Method (PPM), the technique involves "a radically different way" of representing numerical weather data, according to Kelvin Droegemeier, a professor of meteorology at the University of Oklahoma in Norman. Unlike standard numerical methods, PPM "builds into [a weather] problem some knowledge of physics and an understanding of fluid flows," Droegemeier says.

PPM is the brainchild of Paul Woodward, an astrophysicist at the University of Minnesota and the Minnesota Supercomputing Center, and Phillip Colella, an applied mathematician at the University of California at Berkeley. Based on work of S. K. Godunov in Russia and Bram van Leer in Holland, PPM was developed just this decade as a numerical technique for handling the shock discontinuities that arise in supersonic fluid flow problems.

Shock waves are not of concern in meteorology, of course, but it turns out that PPM is generally good at handling problems with steep gradients—and anyone who has ever seen tornado damage can tell you how dramatically conditions can vary in less than a city block.

Droegemeier and Woodward met at a conference on algorithm development at the University of Illinois Supercomputer Center in 1986. The meteorologist was impressed with the way PPM modeled fluid flow. "He [Woodward] showed some videotapes of some astrophysical simulations," Droegemeier recalls. "They looked remarkably like what we were doing in the atmosphere, except his solutions looked a heck of a lot better."

Later that year, Droegemeier introduced PPM to graduate student Richard Carpenter of the Cooperative Institute for Mesoscale Meteorological Studies. Along with Carl Hane at the National Severe Storms Laboratory, Carpenter, Droegemeier, and Woodward have collaborated to develop a meteorological version of PPM. "We weren't sure if it would be appropriate for atmospheric flows, where shock waves are of no consequence and their sister sound waves serve only as a nuisance by severely limiting the time step of the calculation and thus the total computation time," Droegemeier says. "It turns out that PPM works beautifully for atmospheric flows."

The meteorological PPM model is currently restricted to a two-dimensional setting, but in a paper to appear in the *Monthly Weather Review*, Droegemeier and colleagues show that PPM successfully models the turbulent structure of a buoyant convective thermal—the sort of event that leads to the formation of storm systems. They have also used their model for a density current simulation, which is a type of flow that can produce low-level windshears that are hazardous to aircraft.

In a way it's no surprise that astrophysics and meteorology should get together. The two subjects share a common mathematical core in the equations of fluid dynamics. "The same fluid flow equations describe weather on the earth, . . . jets from the nuclei of galaxies, [and] motions of fluids in stars," Woodward explains.

As a consequence, the two subjects also share many of the same mathematical headaches. The most chronic is that the equations of fluid dynamics cannot, in general, be solved exactly. Instead, researchers rely on numerical approximations to tell them what happens when, for instance, a hot plasma shoots through a denser, cooler gas, or when a tongue of cold air plunges down in front of a thunderstorm.

Standard numerical techniques try to approximate solutions by keeping track of variables such as temperature and pressure at a finite set of grid points and updating their values in discrete time steps according to formulas obtained from the fluid equations. The standard techniques run into trouble when there's a shock or sharp gradient: they typically wind up exhibiting spurious oscillations, as if the model suddenly got the jitters. This can be controlled by introducing