Mankind Is Going Back To the Moon!

by Marsha Freeman

NASA

Astronaut Buzz Aldrin descends the Lunar Module ladder as he prepares to walk on the Moon in the 1969 Apollo 11 mission. The photo was taken by Astronaut Neil Armstrong.

China, Russia, India, Japan, and newer spacefaring nations are planning multigenerational great projects to go to the Moon and beyond. Will the United States join them?

Space visionary Krafft Ehricke was well known for his maxim: "It has been said, 'If God had wanted man to fly, He would have given man wings.' Today we can say, 'If God wanted man to become a spacefaring species, He would have given man a Moon.'"

Fifty years ago, Earth's atmospheric barrier was crossed when the Soviet Union orbited Sputnik. During the 1960s, the Soviet Union crossed cislunar space, and visited the Moon with spacecraft, and the United States followed with machines, and then men.

Over these intervening decades, new nations have joined the two first space powers in the ability to launch craft into space. These spacefaring nations are now ready to "break the bonds of Earth-orbit" and send their first probes into deep space. As Krafft Ehricke noted, the natural destination of such an endeavor is the Moon.

William Jones/EIRNS

Sun Laiyan, head of China's National Space Administration: "If we each exchange an apple, we each still have only one apple. But if we exchange ideas, we each have two ideas."

The ability to so clearly see the Moon with the naked eye, and its proximity as compared to any other orb in the sky, has inspired men to discover its nature, and eventually to go there, since ancient times.

Not only the nearness and the beauty of the Moon make it a preferred destination. Our natural satellite is the depository of billions of years of history of the Solar System. Minerals and materials there are of potential value on Earth. The Moon is a unique venue for making astronomical discoveries, and it will be the proving ground and stepping-stone to Mars and even farther destinations.

Since the 1960s Apollo program, it has been a widely held American belief that if we could master the science and technology required to go to the Moon, we should be able to solve any of the other problems we face on Earth. Today it can be said that if men can learn to live on the Moon, it should be possible to live elsewhere in our planetary neighborhood, not only in terms of the development of the technology, but through the success of a multi-decade, generational commitment to such an inspiring and great project.

The next step in the intensive study of the Moon is being prepared for liftoff this Spring, with the launch of the Chinese Chang'e mission. India, the United States, Japan, and Russia are also preparing unmanned missions to the Moon, during 2007-2008. By the end of the next decade of this century, men should be returning to the Moon, to begin an exploration effort that will continue for decades.

A Goddess to the Moon

In 2007, China will take its first step into deep space. The Chang'e spacecraft, named after a goddess who flew to the Moon in a Chinese fairy tale, will be launched to observe the Moon for one year. China's lunar program actually began in 1978, when the United States presented the Chinese government with 1 gram of a lunar sample brought back from the Moon by the Apollo astronauts. After many years of preparation, in 2004, the government of China approved a three-phase lunar exploration program, which is that nation's first foray beyond Earth orbit.

The Chang'e spacecraft will be placed in a 200-kilometer polar orbit. Its scientific objectives include creating a three-dimensional "portrait" of the Moon, especially in the polar regions; analyzing 14 minerals on the surface, to determine the Moon's chemical composition; and studying the cislunar environment, between the Earth and the Moon. A suite of five scientific instruments will carry out these experiments.

According to lunar program chief scientist Academician Ouyang Ziyuan, China will also focus on improving the understanding of the Moon's reserves of helium-3, an isotope not available in abundance on Earth, but resident in the soil of the Moon. In the future, helium-3 will be needed as a fuel for fusion power plants. "The current estimate is between 1 million and 5 million tons [of helium-3 in the lunar soil], and we will try to improve [that estimate] a little," he told *China Daily* last Summer. Were fusion energy to be used to meet global energy demands, he explained, "each year three Space Shuttle missions could bring enough fuel for all human beings across the world."

In order for the lunar program to have the widest impact upon its scientific community, China has established an "expert committee" on the scientific applications of the Chang'e program. Up to 100 universities and institutes will participate, and carry out research using the lunar data sent back from the spacecraft. The committee is to decide on the distribution of research and ensure a wide participation among educational institutions. It has been proposed that scientists from other countries will join the data analysis.

China has had to create a deep-space network to be able to communicate with Chang'e. Large-diameter radio antennae to send commands to, and receive data from, the spacecraft are being built around the country, and China has several monitoring stations in Pakistan, Namibia, and Kenya. In addition, the European Very Long Baseline Interferometry network will join China's deep-space monitoring, during the Chang'e mission. During the European Space Agency's SMART 1 lunar mission, China's antennae contributed to monitoring that spacecraft.

Responding to criticism of China's expenditure of $175 million for its lunar program, Ouyang reported that, compared

People's Republic of China

China's lunar mission is named after the mythical goddess Chang'e, who flew to the Moon. China's first mission beyond Earth-orbit is scheduled for launch this year. Inset is the logo for the Chang'e mission.

Krafft Ehricke's Plan for Industrializing the Moon

Space visionary Krafft Ehricke (1917-1984) developed a detailed five-stage plan for industrializing the Moon and utilizing its vast resources to enrich the Earth's economy and enable a high quality of life for 11 to 12 billion people. Ehricke designed the necessary vehicles, habitats, and industrial processing systems for the Moon's biosphere, and calculated the resources available.

In stage one, simple landers and orbiters would observe, explore, and map the Moon, identifying resources. In stage two, a circumlunar space station would be established, to train and house personnel, develop transportation systems, and experiment with lunar samples. Stage three is the first production phase, with a first-generation Central Lunar Processing Complex and crews that would begin surface mining and drilling, agriculture, and monitoring robotic equipment for construction activities. In this stage, transportation arrangements would be developed for travel between the lunar surface and cislunar space.

In stage four, feeder stations would be established at places where raw materials were found to be abundant. These would be collected and brought to a central processing complex. The lunar population would increase in this stage and become more urbanized. Stage five would see the development of Selenopolis, the the capital city of lunar civilization and the lunar biosphere. Ehricke designed the huge enclosures for the city with different climates and climate cycles, a monorail, and fusion energy plants to power the industrial enterprise.

As Ehricke wrote, "After stage five ... the new world is launched and grows into the future according to its own laws."

A collection of six articles by and about Krafft Ehricke is available on the 21st Century *website for $30: https://www.21stcenturysciencetech.com/Merchant2/merchant.mv?*

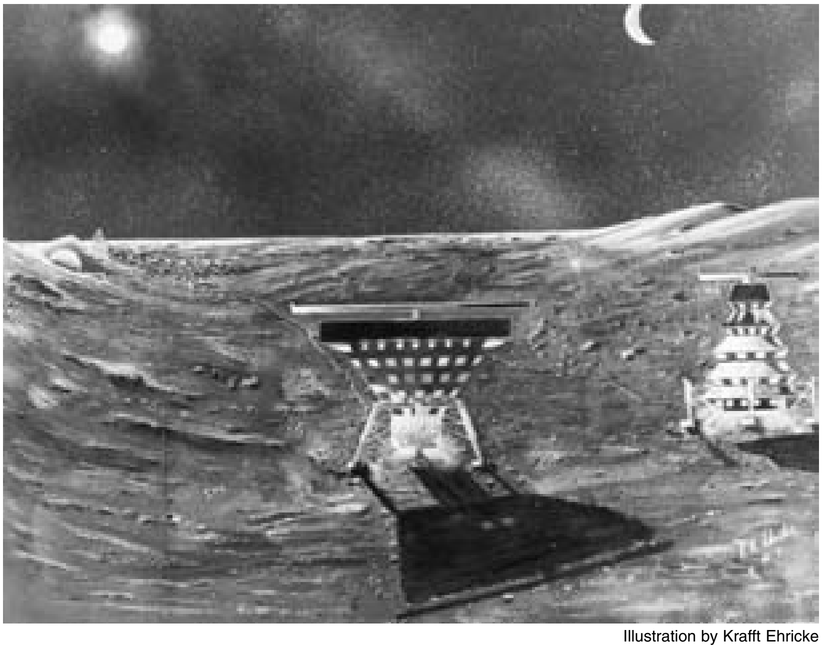


Illustration by Krafft Ehricke

Two laboratory/habitat modules (with more to follow) are placed on the lunar surface, along with a nuclear power station to serve them (its conical radiator surface is visible in the upper left). The inverse converging shape of the modules maximizes shielding against corpuscular radiation, optimizes temperature control for placement in equatorial regions, and serves as an umbrella to provide shade near the module.

Illustration by Krafft Ehricke

Ehricke's illustration of the nuclear-powered sweeper, shown here preparing a runaway for the lunar slide lander, a vehicle designed to touch down at extremely high velocities, transferring its momentum to the lunar dust ocean.

with the huge potential benefits of the lunar program, the same amount of money builds 3 kilometers of subway in Beijing. Last year, Ouyang told a Chinese audience that "the lunar exploration program will have an incalculably valuable effect on the spirit and motivation [of the Chinese people], and I ask you, how much is that worth?"

Answering questions from students at a presentation on China's space program, Ouyang Ziyuan, who has lobbied the government to begin the effort since the late 1990s, explained that China cannot be left out of the enterprise that advances great nations.

The second phase of China's lunar program will center on a soft landing on the Moon of a rover in 2012, to do an *in situ* survey near its landing site. At the Sixth China International Aviation and Aerospace Exhibition in November 2006, visitors saw an initial concept of a six-wheeled vehicle being developed by the Chinese Academy of Space Technology. The third phase, by the end of the second decade of the century, is slated to be a robotic mission that will return samples of lunar rocks and soil to Earth.

The Real Reasons for Space Exploration

On Jan. 19, 2007, NASA Administrator Mike Griffin spoke before the Bay Area Houston Economic Partnership, about the "Real Reasons" versus the "Acceptable Reasons" for space exploration. Excerpts follow.

I've reached the point where I am completely convinced that if NASA were to disappear tomorrow, if the American space program were to disappear tomorrow, if we never put up another Hubble, never put another human being in space, people would be profoundly distraught. Americans would feel less than themselves. They would feel that our best days are behind us. They would feel that we have lost something, something that matters. And yet they would not know why.

If you ask why we're going back to the Moon, and later, beyond, you can get a variety of answers ... for the purpose of scientific discovery, economic benefit, and national security ... to bring the Solar System within mankind's sphere of economic influence.

These reasons have in common the fact that they can be discussed within circles of public policy making. They can be debated on their merits, on logical principles. They can be justified. They are what I am going to call tonight "Acceptable Reasons."

But who talks like that? If anybody asked Lindberg why he crossed the Atlantic—and many did—he never indicated that he personally flew the Atlantic to win the Orteig prize.... When Sir George Mallory was asked why he wanted to climb Mount Everest, he said, "Because it is there." He didn't say that it was for economic gain. We know these reasons, and tonight I will call them "Real Reasons." Real Reasons are intuitive and compelling to all of us, but they're not immediately logical. They're exactly the opposite of Acceptable Reasons, which are eminently logical but neither intuitive nor emotionally compelling.


NASA

NASA Administrator Mike Griffin: "If we didn't have a space program, we Americans would feel less than ourselves. We can never allow that to happen."

As to curiosity, who among us does not know the wonder and mystery and awe and magic of seeing something, even on television, never seen before, an experience brought back to us by a robotic space mission? And how much grander when one of our own, a representative of other human beings, is there to see if for herself? Who doesn't know that feeling?

We like to do what I'll call monument building. We want to leave something behind for the next generation, or the generations after that, to show them that we were here, to show them what we did with our time here. This is the impulse behind cathedrals and pyramids and many, many other things. We could have done a lot of different things to honor George Washington. But what was done, was that in the early 1800s people started to work on a 550-foot high obelisk to honor him. But it is not only George Washington whom the monument honors; it says fully as much about the people who built it.... It is my observation that when we do things for Real Reasons as opposed to Acceptable Reasons, we produce our highest achievements.

The cultural ethos in America today requires us to have Acceptable Reasons for what we do. We must have reasons that pass analytical muster, that offer a favorable cost-benefit ratio that can be logically defended. We tend to dismiss out of hand reasons that are emotional, or are value-driven in ways that we can't capture on a spreadsheet.

When I arrived here tonight, I was told that this very lectern from which I am speaking is the one from which John Kennedy gave the speech you saw earlier ... the JFK quote about space that I love more than anything in the world, because it evokes exactly the things I'm talking about here tonight, was the one he gave from this lectern at Rice University in September 1962, when he said, "We choose to go to the Moon, and to do the other things, not because they are easy, but because they are hard."

The cathderal builders knew that reason. They were doing something that required a far greater percentage of their gross domestic product than we

An International Effort

Unlike the lunar programs of decades past, the missions that are in preparation by India, China, Japan, the United States, and Russia will benefit from shared technology, scientific instruments, and data.

Last July, the eighth conference of the International Lunar Exploration Working Group (ILEWG), was held in Beijing, China. Representatives of 18 nations signed the "Lunar Beijing Declaration," which commits them to coordinate the operation and scientific results of the missions that will be launched over the next two years to the Moon.

The upcoming international exploratory assault on the Moon will take place in three stages. First, a series of four unmanned orbiters will be launched in 2007 and 2008. The Lunar Beijing Declaration proposes that the data from each mission be cross-correlated with the others, especially where more than one spacecraft will be carrying similar instruments. It recommends that common standards be used for spacecraft communications, so they can "talk" to the same Earth-tracking stations, and to each other.

will ever put into the space business.... We look back across 600 or 800 years of time, and we are still awed by what they did.... To me, the irony is that when we do hard things for the right reasons—for the Real Reasons—we end up actually satisfying all the goals of the Acceptable Reasons. And we can see that, too, in the cathedrals, if we look for it.

What did the cathedral builders get? They began to develop civil engineering, the core discipline for any society if it wishes to have anything more than thatched huts. They learned how to build high walls and to have them stand up straight. They learned how to put a roof across a long span. They learned which material would work, and which ones would not ... they created the incentive to solve those problems, so that they could build things beyond cathedrals, so that they could, fundamentally, build Western civilization.

They learned to embrace deferred gratification ... on a societal level.... The people who started the cathedrals didn't live to finish them; such projects required decades. The society as a whole had to be dedicated to the completion of those projects.... We owe Western civilization as we know it today to that kind of thinking—to have a constancy of purpose across years and decades.

It is my contention that the products of our space program are today's cathderals. The space program addresses the Real Reasons why humans do things ... in the practical sense, space really is about spin-offs, as many have argued. But it's not about spin-offs like Teflon and Tang and Velcro as the public is so often told—and which in fact did not come from the space program.... The real spin-offs are a higher level.

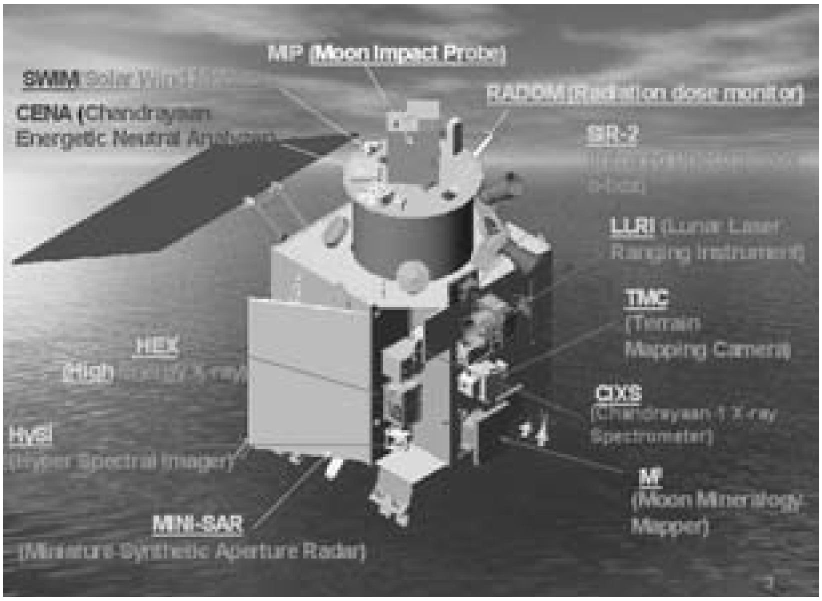
What is the scientific value of discovering the origins of our universe? What is the value of [that kind of] knowledge...? I cannot begin to guess.... Let's think for a moment about national security. What is the value to the United States of being involved in enterprises which lift up human hearts everywhere when we do them?... I would submit that the highest possible form of national security, well above having better guns and bombs than everyone else, well above being so strong that no one wants to fight with us, is the security which comes from being a nation which does the kinds of things that make others want to work with us to do them. What security could we ever ask that would be better than that, and what gives more of that to us than the space program?

What do you have to do, and how do you have to behave, to do space projects? You have to value hard work. You have to live by excellence, or die from the lack of it. You have to understand and practice both leadership and followership.... You have to build partnerships.... You have to be willing to defer gratification, and to spend years doing what we do, and then stand back and see if it works. We learn how to leave a legacy, because we work on things that all of us will not live to see—and we know it. And we learn about accepting the challenges of the unknown, where we might fail, and to do so not without fear or apprehension, but to master it and to control it, and to go anyway.

These are the values that the space program brings. This is why it must be supported. And this is why, although we don't acknowledge it, we don't admit it, and most of us don't understand it, this is why if we didn't have a space program, we Americans would feel less than ourselves. We can never allow that to happen.

NASA

President John Kennedy, September 1962: "We choose to go to the Moon, and to do the other things,not becuse they are easy, but because they are hard."



India's Chandrayaan-1, its first lunar mission, will be international, carrying European and U.S. instruments, in addition to its own imaging instruments.

For the next phase, early in the next decade, which will include unmanned landers, rovers, impactors, and penetrators, the experts suggest that there be coordination in choosing targets for landers, and that the groundwork begin to be laid for the long-term development of the Moon. They recommend that infrastructure be developed jointly for relaying data back to Earth, to aid in navigation around and on the Moon, and to establish a lunar Internet. The Declaration recommends that there be an international scientific working group established to define the common standard for future lunar networks of other instruments.

The Chinese are hopeful that the goal of the Beijing Lunar Declaration, for a coordinated global approach to studying and exploring the Moon, will be implemented. To explain his view of international cooperation, Sun Laiyan, the head of China's National Space Administration, recounted an old Chinese saying at the Beijing conference, which, in paraphrase, counsels: "If there are two of us and we each exchange an apple, we each still have only one apple. But if we exchange ideas, we each have two ideas."

India's International Lunar Mission

Navenda Bhandari, from the Indian Space Research Organization (ISRO), observed at the Beijing lunar conference that "despite one half a century" of space exploration, "we know very little about the Moon. It is the most mysterious and important body in the Solar System." The Moon's historical "link to the solar nebula is the key to understanding the early evolution of the Earth," he said. Over the coming decade, there will be a "continuous presence" of spacecraft at the Moon, and the international scientific community should "debate the priorities and problems."

Chandrayaan-1, which means "Moon-craft" in Sanskrit, will be launched in the first quarter of 2008. It is India's first deep space mission, and was proposed by the Indian scientific community in 1993.

Some of the questions Indian scientists would like to address, according to J.N. Goswami, a planetary geologist from ISRO, include whether there was a magma ocean on the Moon, the Moon's bulk chemistry, the cause and nature of the asymmetry of the near and far sides of the Moon, and how water and other volatiles have been transported throughout the Moon's history.

From the beginning, India decided that its first lunar mission would be international in scope. Chandrayaan-1 will carry three instruments contributed by the European Space Agency, and one from the Space Laboratory of Bulgaria, in addition to those from India. And during the visit of NASA Administrator Mike Griffin to India in May 2006, he and ISRO chairman Madhaven Nair signed Memoranda of Understanding, to allow two American-built instruments to also fly on India's Moon-craft.

The American instruments that will fly to the Moon on Chandryaan-1 are a Mini Synthetic Aperture Radar, being developed by Johns Hopkins University's Applied Physics Laboratory; and a Moon Mineralogy Mapper, being built by Brown University and NASA's Jet Propulsion Laboratory. These were selected from 16 proposals that had been submitted to ISRO from all over the world.

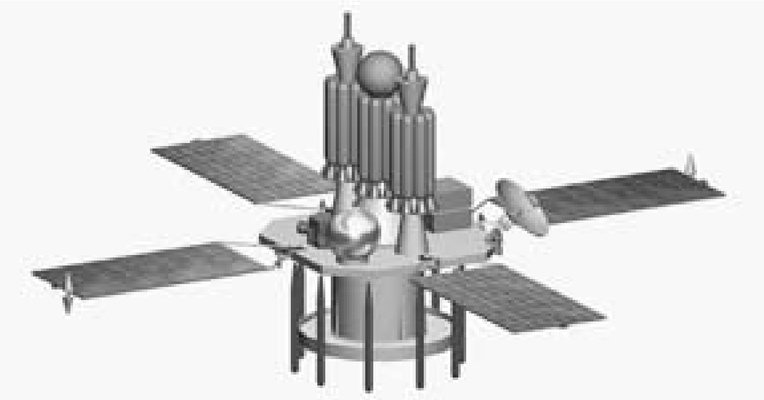
The American instruments, in complementarity with those from India and Europe, will produce composition maps of the surface, and the radar instrument will focus on the poles, examining the bottoms of deep craters, where it is hoped caches of water ice exist.

India's Chandrayaan-1 spacecraft will be in a polar orbit of the Moon at a low, 100-kilometer altitude. The mission is projected to last two years, and carry out high-resolution mineralogical and chemical imaging of the polar regions and of lunar rocks, and mapping of the topography and other features of the lunar landscape.

The spacecraft will also be carrying a small, 29-kilogram impactor, which will be dropped to the lunar surface from the orbiter. During its 100-kilometer, 18-minute fall to the surface, three instruments on board the small probe will take measurements of the Moon's tenuous atmosphere, instantaneous altitude, and video-imaging. The orbiter will observe the dust that is kicked up from the crash upon impact. The impactor is also designed to qualify some of the technologies that will be needed in the future for soft landings on the Moon.

India is already designing a follow-on Chandrayaan-2 mission, which would land a motorized rover on the Moon, in 2010 or 2011. According to a report in *The Hindu* on Jan. 4, 2007, the 30- to 100-kg rover would have an operational lifetime of a month. It would be able to do *in situ* chemical analysis on lunar soil samples, and send the data from the results to the orbiting mother spacecraft, which would then transmit the data back to Earth. To operate for a longer period, it would include a battery backpack that could be recharged.

ISRO Chairman Madhaven Nair told the *Press Trust of India* on Feb. 5, 2007, that Chandrayaan-2 will be undertaken by



Russia's Lunar-Glob may be ready before its planned launch in 2012. It will robotically explore the Moon with an orbiter and send penetrators to the lunar surface.

2010. "It will have a lander which would touch down on the lunar surface and pick up samples," he said.

Looking further into the future, Indian scientists are planning to join Russia, the United States, and China, in the capability of launching Earth-orbital manned missions. In September 2006, ISRO Chairman Nair told a conference in Bangalore that an Indian human space mission "is on the top of the agenda of the long-term space program of the country, as space will be the next frontier for human beings." In the Feb. 5 interview, Nair reported that the Government had given the go-ahead for ISRO to prepare a report on the manned space mission. The "study project has been cleared," he said. "By the end of the year, we will be submitting a firm project report to the Government."

India is already making progress on the array of technologies required to put people into space. On Jan. 10, India launched its Space-Capsule Recovery Experiment (SRE-1). On Jan. 22, the 1,213-pound (551-kg) spacecraft splashed down in the Bay of Bengal, becoming the first Indian spacecraft ever recovered after a mission in orbit.

The purpose of the experiment was to test a thermal protection heat shield that would protect a crew inside through the heat of reentry; an onboard propulsion system, that must ignite to bring a craft out of orbit and back to Earth; a guidance, control, and navigation system to guide the capsule to a precise landing; and a recovery system for land or sea. Reports so far indicate all of these critical systems operated as designed.

As data come back from the Indian and other lunar craft, and progress is made on the technologies required for manned space flight, India will be prepared to join the international effort to bring human civilization to the Moon.

Russia to Return to the Moon

In the late 1950s, the Soviet Union took an early lead in lunar exploration. Most of the craters on the far side of the Moon, which is not seen from the Earth, are named for Russian scientists, because the craters were photographed for the first time by the Luna-3 spacecraft. Soviet spacecraft produced stunning results from a series of 20 successful robotic lunar missions through the mid-1970s, which brought back soil and dust samples from the Moon. Over the subsequent three decades, the Soviet Union, and then Russia, concentrated on missions to Venus and Mars.

Russian scientists have described a new Moon mission called Lunar-Glob, to robotically explore the Moon with an orbiter, and deploy penetrators around the lunar surface. At the conference in Beijing, Academician Erik Galimov, director of the Vernadsky Institute of Geochemistry and Analytical Chemistry, described the Lunar-Glob project, to study the seismology and internal structure of the Moon, which will shed light on its origin. The orbiting spacecraft would deploy 13 high-speed penetrators into the top layer of the lunar surface.

According to the current design, two of the penetrators will be aimed at the Apollo 11 and Apollo 12 landing sites, to retrieve subsurface data complementary to that obtained during the U.S. manned missions, 37 years ago. Another 10 high-speed penetrators are to form a distributed seismic network. After firing the penetrators, the orbiting mother ship would drop a small lander into a crater at the Moon's south pole, to search for signs of water ice.

Lunar-Glob has been scheduled for launch in 2012. But at the July conference, Academician Galimov said he was delivering a "message": that it is possible the lunar mission will be ready three years earlier. The Russian Phobos-Grunt mission is to be launched to return samples from Phobos, a moon of Mars, in 2009. Because the two spacecraft would be similar, the design and manufacture of the lunar spacecraft should be able to be accelerated.

The isotope helium-3, a fuel for advanced thermonuclear fusion reactions, will be a foundation of the next stage, which is the "economic utilization of the Moon," Dr. Galimov stated. He explained that the concentration of helium-3 in the lunar soil, or regolith, is very low, but "the amount is enormous." To obtain this resource, "billions of tons of lunar soil must be mined." Although he proposed that the "deployment of such a mining industry will take 50-70 years," he emphasized that since we have no choice, "we should get started as early as possible!"

The fusion of helium-3 with deuterium was first observed in 1939. In an advanced fusion reactor, helium-3 would be combined with deuterium, the heavy isotope of hydrogen available in seawater, to produce helium-4 and a high-velocity proton. Electricity can be extracted directly from the fast-moving proton, instead of having to first convert the reaction energy from heat into electricity. As there are no neutrons in the reaction, the breakdown of reactor materials by nuclear transmutations is avoided. The fusion reaction can produce higher temperatures and greater energy-density than its next-best competitor, the nuclear fission reaction, and thus will be the energy source of the future.

Nikolai Sevastyanov, head of Russia's mammoth Energia Rocket and Space Corporation, has been actively promoting the mining of helium-3 on the Moon, to help solve the problems of the shortage of energy resources on Earth. Energia is developing plans for the technology needed to mine the Moon, as well as new vehicles to carry machines, and perhaps men, back to the Moon. "The Moon has vast reserves of helium-3," he said last year, "and this is the closest place to Earth where it can be extracted."

Russian space officials have indicated that international cooperation will be key to their proposed lunar projects.

Japan Aerospace Exploration Agency

Artist's drawing of Japan's Selene mission, which includes an orbiting spacecraft and two small satellites. Selene will relay communications, and create a gravity map of the Moon.

During the 36th Congress of the United Nations Committee on Space Research (COSPAR), held in Beijing in July 2006, Nikolai Sanko from the Russian Federal Space Agency, Roskosmos, reported that Russia and China are holding talks on joint programs for lunar exploration. "It is not ruled out that our devices or means for sampling the lunar surface will be installed on Chinese [spacecraft], and that Chinese devices will be installed on Russian craft," he told Itar-Tass.

In November 2006, the deputy head of the Russian Federal Space Agency, Yuri Nosenko, told a press conference in Beijing that Russia regards China as a "partner" in space exploration. China and Russia are currently cooperating in 38 projects related to space, he said, and regarding a lunar project, "the two countries have different strengths that can supplement and benefit each other." Collaboration on future Mars missions is also under discussion.

At this time, unless economic policies are changed, it is doubtful that Russia would mount a manned mission to the Moon on its own. Partnering with China is one option. In December 2006, Russian space officials also voiced interest in participating in the lunar base project that the U.S. space agency had recently outlined.

Dismissing allegations that there is now a rivalry between the United States and China for the next manned mission to the Moon, Igor Panting, spokesman for Roscosmos, said on Dec. 7, that "space research is a vast field with plenty of room for every nation."

Ambitious Designs on the Moon

In 1990, Japan initiated its lunar exploration program, launching its Hitan spacecraft and becoming the third nation in the world to launch a mission to the Moon.

Japan's space scientists and mission planners have developed a very creative, and highly complex series of lunar missions, and because of very difficult technology challenges, one of its planned lunar missions, Lunar-A, was cancelled on Jan. 15. It was to carry out seismic studies, by slamming a pair of penetrators, to a depth of 10 feet into the lunar soil. But the penetrator technology still requires development, and will likely be applied to a later mission.

Japan is now in the last stages of readying its Selene spacecraft—Selenological and Engineering Explorer—to be launched to the Moon in 2007. At the International Lunar Exploration Working Group conference in Beijing last July, Dr. Hajime Inoue, from Japan's space agency, JAXA, explained that Selene consists of three spacecraft—a main craft that will be in a 100-kilometer altitude polar orbit, and two small daughter satellites.

One small satellite, called Rstar, will function as a communications relay, to transmit data from the orbiter to Earth when the orbiter is on the far side of the Moon and out of Earth contact.

Dr. T. Iwata from JAXA explained the importance of the second small satellite, Vstar. Estimates of the gravity field on the far side of the Moon have been made indirectly by observing the perturbations in a satellite's orbit as it circles the Moon, he said. But the measurements are not precise. Vstar will do global mapping of the Moon, with a focus on the gravity variations.

Dr. Iwata also reported that using both small satellites in tandem will allow scientists to determine their position within 20 centimeters of accuracy, by establishing a very long baseline interferometry network. These assets, for relay communications and precision navigation, are a forerunner of the kind of permanent infrastructure that will be needed for future exploration of the Moon.

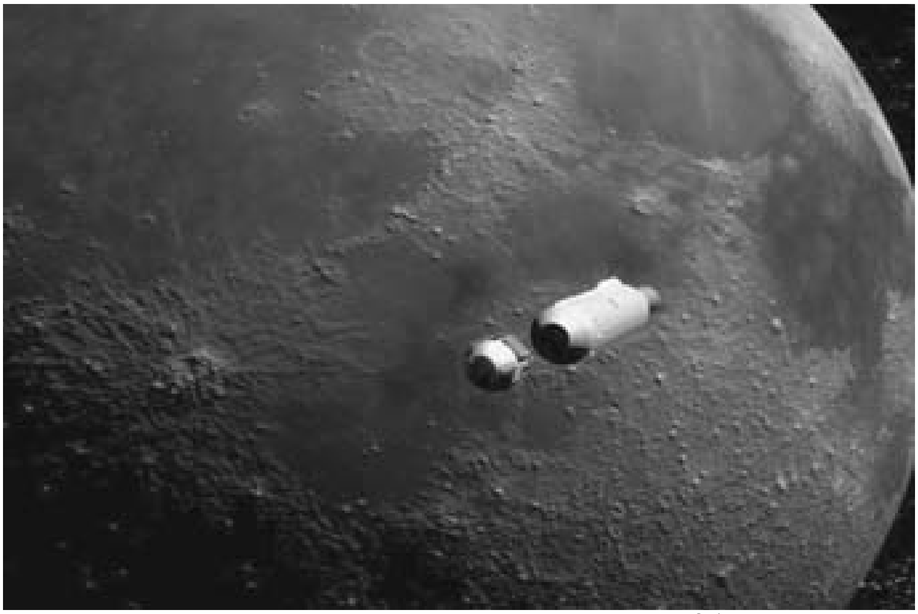
The Selene orbiter will carry an extraordinary complement of 14 scientific instruments, to study the topology, chemistry, magnetic fields, and other characteristics of the Moon and its environment. JAXA also plans to broadcast real-time images from the Moon to the public, to create interest and excitement about the program.

A Crash Landing on the Moon

NASA's contribution to the lunar armada is the Lunar Reconnaissance Orbiter (LRO), slated for launch in October 2008. LRO will orbit the Moon at an average altitude of only about 30 miles (50 kilometers), for at least one year, and image our neighbor with unprecedented resolution. As a precursor mission to future human lunar exploration and settlement, LRO will be using a suite of instruments to try to characterize what are assumed to be deposits of water ice at the lunar poles.

The 50-km orbit is very challenging, and this will be a first attempt at such a low-altitude mission. Close to the lunar surface, the spacecraft's orbit becomes unstable because of the gravity variations of the Moon. Active propulsion onboard the craft will, therefore, be used to keep it in a stable orbit. In addition to all of its scientific objectives, LRO will also image the historic U.S. and Soviet landing sites on the Moon, including NASA's unmanned Ranger and Surveyor probes, and sites where the Apollo astronauts walked. Soviet Lunakhod rovers should also be visible. At such high resolution, even relatively small craters should be able to be imaged, and scientists expect to see hundreds of craters in the 10-meter range, for the first time.

As NASA was developing the LRO spacecraft, an opportunity presented itself to give a piggyback ride to a small companion craft; and in April 2006, the space agency chose the Lunar Crater Observation and Sensing Satellite, or LCROSS, to hitch a ride on LRO. It will take measurements when the upper



NASA/John Frassanito Associates

NASA's Lunar Reconnaissance Orbiter, here in an artist's drawing, will dispatch a small shepherding spacecraft (left) to make observations as the rocket's upper stage impacts the lunar South Pole.

stage of LRO's rocket slams into the hydrogen- and potentially water-rich Shackelton Crater at the south pole of the Moon. About 15 minutes later, after the booster's upper stage makes its impact, the LCROSS probe itself will crash into the crater floor. Scientists hope to be able to verify that the enhanced hydrogen signature that has been previously measured, indicates the presence of water ice.

Man on the Moon

When U.S. President George W. Bush outlined his Vision for Space Exploration in January 2004, the first destination planned beyond Earth orbit, was the Moon. In December 2006, NASA released its lunar architecture—an outline of how NASA will carry out that program. The south polar Shackelton Crater was chosen as the preliminary choice for the base on the Moon, because it is almost permanently sunlit, but is adjacent to a permanently dark region, where it is expected there are caches of water ice, deposited throughout eons by comets.

The first manned missions, to be carried out beginning by the year 2020, is to be a series of seven-day "sortie" missions by a crew of four, on the lunar surface. Each short-duration manned mission, and unmanned cargo flights, will build-up logistics capabilities, equipment, and materiel, aiming for the establishment of a permanently crewed lunar outpost.

But before sending people, NASA had planned a series of unmanned precursor missions, to do further exploratory work, and to test capabilities, such as a new lunar lander, that are critical for manned missions. Since President Bush's announcement of the Vision for Space Exploration, however, the White House has refused to submit a budget to the Congress that is adequate to fund the program. With the accumulated shortfalls in funding, NASA Administrator Mike Griffin has announced that lunar precursor missions to follow the Lunar Reconnaissance Orbiter, will be delayed, or cancelled.

On March 16, NASA notified the Johns Hopkins University Applied Physics Laboratory that it was allowing its contract to build a robotic lander to expire at the end of the month. The lander, developed under the guidance of NASA's Marshall Space Flight Center's Lunar Precursor and Robotics Program Office, was to launch, unmanned, to the Moon in 2011 to demonstrate advanced descent and landing techniques, and determine whether the lunar poles do contain water ice, before people are sent there. Since there are now no further precursor missions planned, the space agency also indicated that it was going to close the Marshall lunar projects office.

In order to return to the Moon, NASA must develop a new spacecraft and launch system. There are not adequate funds in the budget to develop the new Crew Exploration Vehicle, or Orion, and its Ares launch vehicle, while completing the International Space Station using the Space Shuttle. If the program continues along the current path, it is inconceivable that the United States will make it back to the Moon.

In a speech to the annual Goddard Space Symposium on March 20, Administrator Griffin stated that because of President Kennedy's 1960s Apollo program, "America has been the leader on the space frontier for the past two generations." Similarly, at a Washington press conference on Dec. 4, 2006, when the lunar outpost architecture was released, Exploration Deputy Associate Administrator Doug Cooke observed that the Apollo missions were "tremendous," and that "most of us are here because we were watching those, at the time, as we grew up."

Where will that inspiration come from, for the next generation?

In June 2006, officials from China's space program made the announcement that following the successful completion of its three-stage robotic exploration of the Moon, China is planning a manned lunar mission, in 2024. Although this led to intense speculation in the western media of a new "race to the Moon," in a replay of the U.S.-Soviet competition of the 1960s, China has gauged the timetable for its manned space program strictly by the progress of the endeavor, and has made it clear that it is anxious to carry out such programs with international partners.

China, Russia, India, Japan, Europe, and newer spacefaring nations are planning their multigenerational great projects for space exploration. There is no better arena for international cooperation than the exploration of the Solar System. The window of opportunity is open.

Marsha Freeman is an associate editor of 21st Century *and technology editor of the weekly* Executive Intelligence Review. *She is preparing a biography of Krafft Ehricke, which will include reprints of his extensive work on colonizing the Moon.*