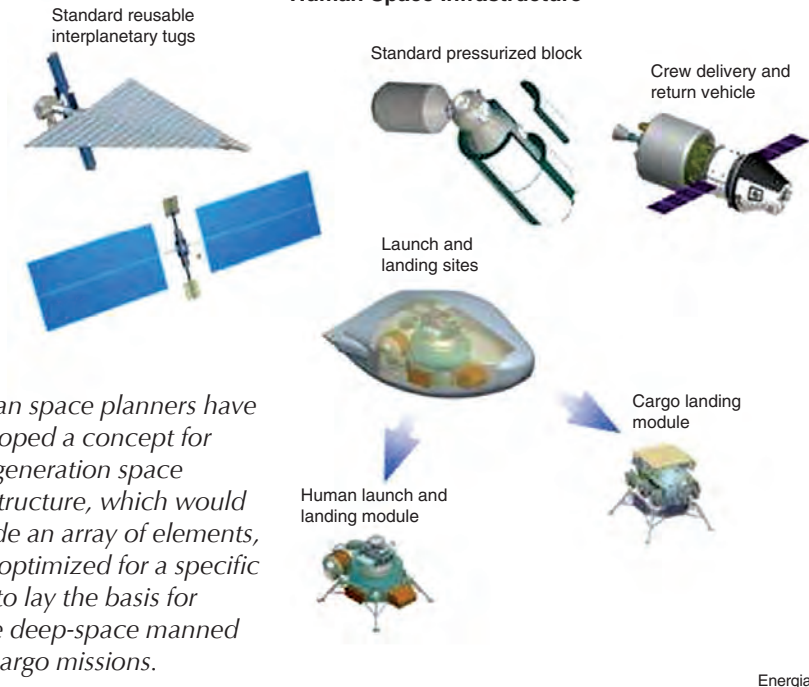


Standard Elements for the Human Space Infrastructure



Russian space planners have developed a concept for next-generation space infrastructure, which would include an array of elements, each optimized for a specific task, to lay the basis for future deep-space manned and cargo missions.

INTERNATIONAL ASTRONAUTICAL CONGRESS

Space Scientists Meet Amidst Uncertainty and Hope

by Marsha Freeman

As space scientists, engineers, and program managers gathered for the annual International Astronautical Congress (IAC) during the first week in October, the global financial and economic crisis cast a pall over the creative and visionary plans put forward by representatives from more than 70 nations. The crisis, referred to by many of the national space agency representatives, has left the future of space exploration plans uncertain, especially in the United States and Europe. As if to put a point on the crisis, during the week-long Congress in Naples, Italy, a one-day transport workers strike left the more than 4,000 IAC participants

scrambling for alternate ways to get to the conference.

Due to budget cutting, many of the visions and goals for future manned exploration and space science missions have narrowed. Mission planning is often circumscribed within what is considered to be “affordable,” or “sustainable” (whatever that means for space exploration).

But the missions that are being carried out today are a testament to the stubborn refusal of space planners to acquiesce to the prospect that there will be no tomorrow. The International Space Station (ISS) partners are looking forward to the next goals for

manned space flight, as the assembled station evolves into a base for scientific investigation and preparation for deep-space manned missions. The stunning accomplishment of NASA’s Curiosity rover’s landing on Mars helps to lay the basis for more extensive and intensive unmanned planetary investigation, and poses the questions for the next steps on Mars.

The newer space nations, particularly China and South Korea, reported on their plans to expand their range of space activities, to become major participants in global exploration. And newly emerging space nations, such as South Africa (which presented 23 papers at the Naples Congress), are, despite desperate domestic economic situations, pushing forward to use and develop space technology, with the understanding that developing such capabilities is a fundamental underpinning for real economic growth.

Even though many of even the most optimistic space planners presented new ideas and proposals with hesitation, often with the caveat: “This program has not yet been approved,” participants recognize that what they do, plays an important role in *creating* the future.

Station Complete: What’s Next?

Over the past year, the Herculean task of assembling the International Space Station has been largely completed, with just a few Russian modules remaining to be deployed. But the retirement of the Space Shuttle last year has left the station entirely dependent upon Russian transport, without any back-up system for the American, Russian, European, Japanese, and Canadian crew members. Now, various proposals are under consideration to develop future Earth-orbital and then deep-space transport alternatives. But the overarching question, which would determine

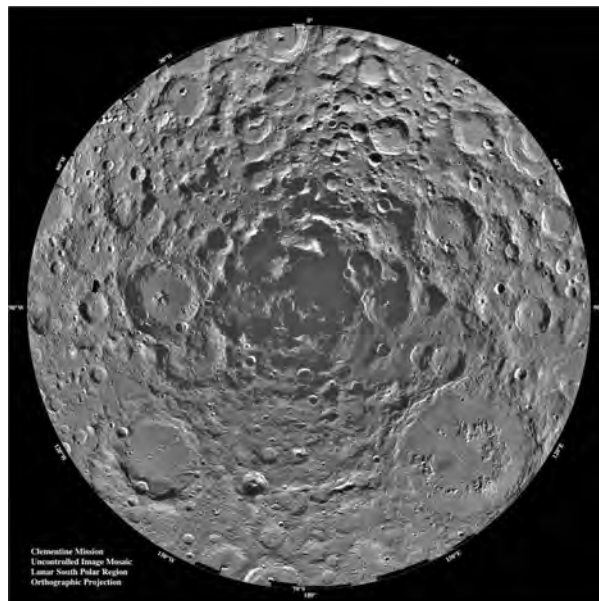
which transportation and other infrastructure capabilities should be developed, is: "Where do you want to go?"

For the past year, the world's space-faring nations (minus China, which, thanks to the United States, is excluded) have conducted studies designed to answer that question. The near-unanimous conclusion is that the Moon should continue to be intensively studied robotically, in order to lay the basis for the exploitation of lunar resources, scientific observation, and future manned missions. The fly in the ointment has been the Obama White House, which, for no justifiable reason, has nixed lunar development as the next goal, opting instead for an imaginary manned mission to an asteroid.

At this year's IAC in Naples, challenging proposals were put forward, which take a longer view, and move from past individual, single-goal missions, to a long-term project of development of space infrastructure. Russian speakers at the Congress, in particular, outlined this approach to create the basis for a multi-decade exploration of space, rather than planning one mission at a time. It is clear to planners looking two or three decades into the future, that the next leaps forward in manned exploration of the Solar System will require an entirely new approach.

The Space Station, in order to offer the widest array of capabilities and to engage the largest number of participants, became "all things to all people," often with conflicting tasks. In Naples, Russian presentations offered a more rational approach for the future: an "open" rather than a "closed" space station architecture.

The "open architecture" approach was described in a paper by Oleg Saprykin and colleagues, from Rus-



The 12-mile-wide Shackleton crater, at the lunar south pole, harbors caches of water ice, in the permanently shadowed regions on the crater floor (in the center of this image). Its peaks are in near-perpetual sunlight, also making it a prime target for future lunar exploration.

sia's Central Research Institute of Machine Building. This Institute—abbreviated TsNiiMash—is the Russian space program's think tank, tasked with analyzing proposals and approaches for future space exploration.

Next-generation stations must be "flexible and adaptable," TsNiiMash proposes, made up of orbital clusters of independent modules, which can be reconfigured and recombined. The value of creating specialized modules, rather than one all-purpose station, was made clear in the presentation, which showed how materials science experiments, geophysics investigations, life sciences experiments, astrophysics observations, and technology experiments carried out simultaneously, on one large facility, can pose conflicting requirements and interfere with each other on the ISS. A smaller core station, with attendant specialized modules, is more adaptable, and enables the focus of research to change with new developments.

The Time Is Now Ripe

Dr. Alexander Derechin, deputy chief designer of the S.P. Korolyov Rocket and Space Corporation Energia, also suggested in his presentation, that the replacement for the ISS, when it has reached the end of its useful life, should be, not another large, highly complex, and expensive multi-purpose facility, but a smaller base that includes a "cloud" of dedicated, autonomous, man-tended modules. Although the basic hardware would be more economically "mass produced," each module would have a specific purpose, for which it would be optimized, and could be "man-tended," rather than continuously occupied. Derechin mentioned a module for astrophysics, oriented to look out at the heavens; one for geophysical studies

and remote sensing, looking down on the Earth; a module for the production of materials and biological products in microgravity, absent the disruptive vibrations caused by the movement of humans; and a module to test and verify advanced technologies.

Derechin placed his future space complex cluster in the context of what he proposes for the next 40-50 years: the continued build-up of Earth orbit infrastructure, an Earth-Moon transport system, a lunar base and the exploitation of resources, and the infrastructure to extend human missions beyond the Moon.

This approach is not new, but the time is now ripe. For the past decade, manned space exploration has centered on missions aboard the International Space Station. Now is the time to set new goals. The infrastructure described by Derechin, which he likened to the development of terrestrial infrastructure elements—roads, canals, ports, power

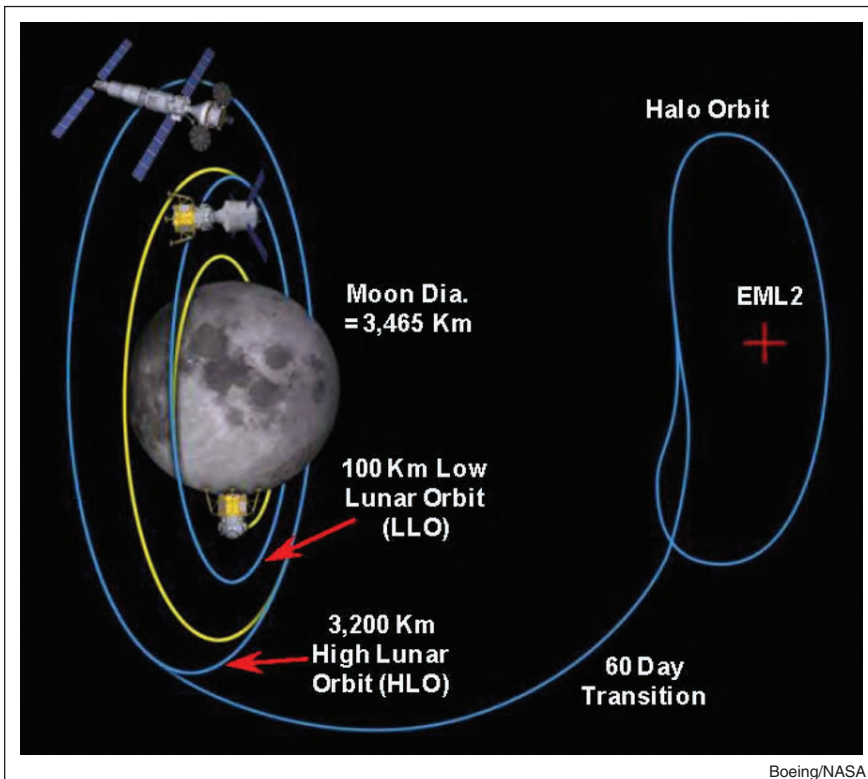


Figure 1

A spacecraft that is placed in a halo orbit at the Earth-Moon Lagrange-2 point (EM L2) would need very little energy to stay in place. This region in space is about 64,000 km farther from Earth than the Moon is, and would be a low-energy transfer point to lunar orbit, as seen here.

supply networks, and communications—can, like the ISS, be deployed in low-Earth orbit.

But to set mankind on a pathway that can more efficiently service multiple decades of missions to multiple destinations, it is increasingly being proposed to locate next-generation in-space infrastructure at an Earth-Moon Lagrange point, about 64,000 km outside the Moon's orbit around the Earth. At this L2 point (**Figure 1**) gravitational forces and orbital motions between the Earth and the Moon balance each other, such that a spacecraft placed there will need very little energy to maintain what is described as a "halo" orbit.¹ From the L2 point, a spacecraft can more easily

1. See Dr. Robert W. Farquhar, *Fifty Years on the Space Frontier: Halo Orbits, Comets, Asteroids, and More* (2011).

head to any deep space destination, without having to expend the energy to climb out of the gravity well from a planet's surface, or break free of a planet's orbit. Destinations could be to lunar orbit, to Mars, to an asteroid, or elsewhere in the Solar System.

In Russia, "we are close to deciding on a Lagrange point [space] station," Derechin said in his presentation. Because "we don't know yet" what the next destination will be, the "new principle for infrastructure" should be that "it is not so dependent on the task."

A Cislunar Gateway

A second paper in Naples, which Dr. Derechin co-authored with Michael Raftery from Boeing, zeroes in on a specific mission concept for lunar exploration, based on an L2 platform. The authors propose that operations in this cislunar region (between

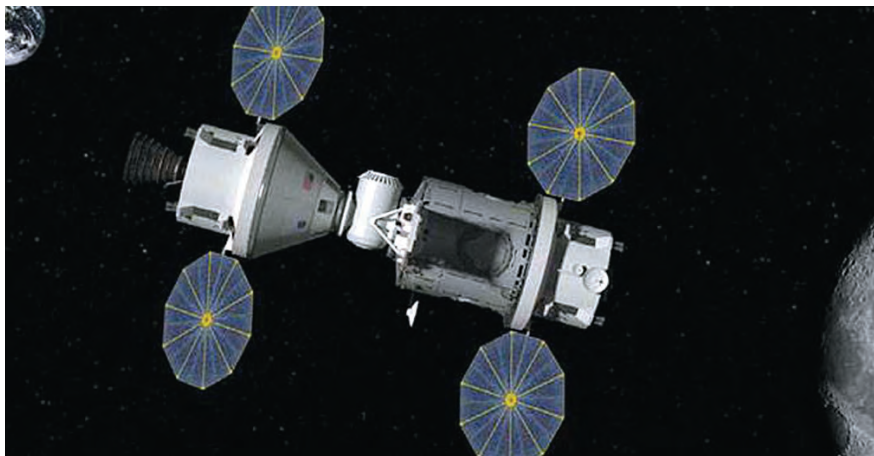
the Earth and the Moon) in the near-term, would be integrated with the existing space station infrastructure.

Placing space assets at the Earth-Moon L2 point has advantages over other Lagrange points, or lunar orbit. It can provide global access to the lunar surface, without restriction or limitations on landing sites. As the L2 point is positioned behind the Moon, relative to its orbit around the Earth, a platform there could be in communication with Earth from the far side (non-Earth-facing hemisphere) of the Moon. Dr. Robert Farquhar had proposed that a communications relay satellite be placed at the L2 point during the Apollo missions, so the crew would not be out of contact with Mission Control, but that was not done.

Raftery and Derechin explain that their Exploration Platform at L2 could be used as a base for a small, reusable lunar lander, which could be refueled and maintained there. The Platform, the authors suggest, could itself be moved from L2 closer to the Moon, in a high lunar orbit, from which it would deploy a surface vehicle, using less propellant for the landing system.

It is highly unlikely that crews would have long stay-times in cislunar space, as the cosmic radiation is comparable to other deep-space locations. Robotic and teleoperated robotic systems would carry out the next phase of lunar exploration, and deliver supplies to the surface, before the infrastructure were in place for manned landings.

While Lagrange point missions for exploration are under serious study in Russia, NASA has also taken a look. In Naples, NASA associate administrator, Human Exploration and Operations Directorate, Bill Gerstenmaier, commented on studies that have been done, describing the gravity "rivers" that could be followed to chart out the frontiers of exploration. Starting from a halo orbit around L2, Gerstenmaier said, an Orion manned capsule, now



NASA

Various designs are being developed to place infrastructure at the Earth-Moon L2 point. In this artist's depiction, a NASA Orion manned space capsule (left) launched from Earth, has linked up with a platform, or "gateway" facility, to be placed at the L2 point, for more efficient travel to further reaches of the Solar System.

under development, could be linked to a new kind of craft—a deep-space vehicle—which would leave the L2 port for an asteroid or Mars.

But a week earlier, NASA issued quick denials when the *Orlando Sentinel* reported the possibility that the space agency would be building a "gateway spacecraft" at the Earth-Moon L2 point as its next step in human space flight.

On Sept. 25, a NASA statement said that the agency was considering "many options" to reach the ultimate aim of sending people to Mars, adding: "We have regular meetings with OMB [Office of Management and Budget], OSTP [zero-growther John Holdren's Office of Science & Technology Policy], Congress, and other stakeholders to keep them apprised of our progress on our deep-space exploration destinations.... President Obama's current policy is to send humans to an asteroid by 2025."

A variety of unmanned, scientific spacecraft have already taken advantage of the unique characteristics of Lagrange equilibrium points between the Earth and the Moon, and the Earth and the Sun. More are planned.

As Derechin explained at the IAC, developing technologies for infra-

structure-building and man-tended facilities at these Lagrange points will not be a simple matter of extending what we use in Earth orbit, but will challenge scientists and engineers to create the means, for the first time, to develop deep space.

Overall, it is important to recognize that there is no rationale to go to a Lagrange point in space as a destination. It is useful to populate it with infrastructure along a pathway to somewhere else. As with the comprehensive space infrastructure proposals on the table from Russian experts, these capabilities must be developed because there is a plan to go somewhere.

In the meantime, on the heels of new discoveries from ongoing missions to the Moon, more ambitious programs are being planned, to bring this nearest part of the Solar System within the domain of human activity.

Regardless of President Obama's idiotic assertion that we need not go back to the Moon, because "we've been there, done that," only a tiny percentage of the lunar orb has actually been intensively studied, and new discoveries from recent missions carried out by the U.S., Europe, Chi-

na, and India have prompted a renewed thrust toward the Moon.

Learning To Land

Only the United States and the Soviet Union have successfully landed spacecraft on neighboring bodies in the Solar System. Thanks to recent scientific results indicating caches of precious water ice captured near the south pole of the Moon that are even more extensive than previously estimated, numerous nations are now planning to deliver scientific instruments to the lunar surface, to make their first *in situ* investigations. Recently, for example, an analysis of data from NASA's Lunar Reconnaissance Orbiter indicates that water ice may make up as much as 22% of the surface material in the lunar south pole Shackleton crater. Such a cache could be the raw material for chemical rocket fuel, and oxygen for future crews.

It has been known since the 1990s that permanently shadowed regions on the floor of the huge, 12-mile-wide Shackleton crater have been the collection point for water ice arriving at the Moon, most likely from comets and meteorites. This extremely cold and dark region near the south pole, therefore, has become a preferred destination for more intensive study.

The European Space Agency (ESA) has proposed a Lunar Lander project, which it hopes will be approved in November at the ESA Ministerial Council meeting. The objective is to demonstrate Europe's first soft precision landing, as a precursor mission to future human lunar exploration. Launch would be planned for the end of 2018, with a landing near the Moon's south pole. The challenges include the development of precision navigation and control to safely set the lander down in a region where it must avoid hazardous slopes, obstacles, and, because it is solar powered, shadowed areas.

The payload carried to the surface by the Lunar Lander would examine

the properties of lunar dust, the plasma and electric field environment on the surface, the feasibility of making radio astronomy observations, the chemical content of the regolith (soil), and measurements of the radiation environment.

The early Soviet space program carried out a very successful robotic lunar exploration program, starting only two years after the 1957 launch of Sputnik. That history was dramatically recalled in a paper in Naples, by Prof. Vyacheslav Ivashkin, from the Kel-

dysh Institute of Applied Mathematics. But as scientists point out, all the data from more recent missions makes this in effect a “new” Moon, which requires more advanced high-precision landing, multiple assets operating at once, and the ability to operate under the Moon’s most extreme environment.

At the IAC in Naples, it was reported that the delayed Russian Luna-Glob project has been split into two missions, which are both under development. The failure of the Phobos-Grunt mission to Mars nearly a year ago, led to a reexamination of the upcoming lunar missions, and, according to officials from the Lavochkin Aircraft and Space Design Bureau, which designs and builds Russia’s planetary spacecraft, some updating of the lunar spacecraft systems has been done. Scientists also wanted to be able to deploy more payload—up to 50 kilograms—than originally planned. Splitting the Luna-Glob program into two missions means there is more room available for experiments on each spacecraft, Roscosmos head Vladimir Popovkin explained earlier this month. The updates and changes that were made in the missions were approved by the



ESM

The European Space Agency hopes to gain approval at a Ministerial Council meeting in November, to proceed with Europe’s first soft landing on the Moon. Launch would be in 2018.

National Academy of Sciences this Summer.

At present, the plan is for a 2015 launch for Luna-Glob 1, which will demonstrate the soft landing of a small craft, to test new technologies. It will be followed the next year by the Luna-Glob 2 mission, which will deploy an orbiter, to study the Moon from a 500km, then 150km, and finally a low 50 km altitude. “We must touch down on the Moon in 2015,” Lavochin’s director general, Viktor Khartov, told ITAR-Tass on Oct. 12. “The Phobos probe failure is a scar on all of us,” he said. “We must touch down on the Moon to show ourselves that we can do it.” The Moon missions have been fully funded, he stated.

The Luna-Resurs mission, scheduled for launch in 2017, will be a 200kg “scientific station,” able to drill for and analyze samples at the lunar south pole. Speaking at the third International Solar System Symposium in Moscow on Oct. 12, Popovkin and Director of the Space Research Institute of the Academy of Sciences Lev Zelyony described the Luna-Resurs as “heavily laden” and “heavily tasked.” Upon touchdown on the surface, the lander will release a small Indian robotic rover.

Even in the U.S., where the Administration has downplayed the importance of the exploration of the Moon (although with some backtracking, in the face of strident criticism), new designs for small rovers are being developed, and scientists and engineers continue to develop possible future missions.

In Naples, the U.S.-Canadian RESOLVE mission was described, which is designed to land near the permanently shadowed regions of Cabeus Crater, to investi-

gate the concentration of volatiles, such as water ice. The Regolith and Environment Science and Oxygen and Lunar Volatiles Extraction mission could be launched in 2016. The Canadian Space Agency is designing a rover for the mission, and a drill, which would be one of the scientific payload elements.

Like the lander designs proposed by ESA, RESOLVE is being designed as a solar-powered system. The rationale is that solar systems are cheaper, and because they are lighter, also reduce the weight of the spacecraft, and, therefore, the cost of launching it. The drawback is the constraint imposed, to find a sunny spot for solar recharge, when, depending upon the landing site, a rover is going to spend at least some time in darkness. William Larson, from NASA’s Kennedy Space Center, explained that with solar power, the proposed mission would last only six days!

Japan and China, which have already operated spacecraft in lunar orbit, are now planning their follow-on missions which will include landers. The Chang’e 3 craft, scheduled to be launched next year, will position China as the first nation to make a soft landing on the Moon in more than 30

years. Unlike comparable missions, Chang'e 3 will include a nuclear "battery," containing plutonium 238, to provide heat and power, similar to the arrangement on NASA's Curiosity Mars rover.

Japan's SELENE 2 is under study, to also include a lander and rover, although without the advantage of nuclear isotope technology. The team from the Japan Space Exploration Agency (JAXA) which presented the SELENE-2 plans, reported that "because of the shortage of the government budget, [the] development plan [for] SELENE-2 is delayed." Even the 2017 launch schedule, they reported, "is not authorized yet."

A new entrant to lunar exploration is South Korea. Representatives from the Korea Aerospace Research Institute (KARI) reported on the conceptual design for a lunar lander demonstrator. A ground-based demonstrator has been developed to test the feasibility of basic structure and design, and landing technologies.

The timetable presented for the Korean lunar orbiter and lander is pushed out past 2020, it was reported, because a Korean rocket launcher that can lift the necessary payload is not scheduled to be ready until then.

Prelude to Returning Samples from Mars

The holy grail of Mars exploration in the scientific community has been the collection of carefully selected Martian soil and rock samples, and their return to Earth. No matter how sophisticated the analytic equipment put on unmanned rovers may be, there is no substitute for subjecting pieces from Mars to the analytic capabilities of laboratories on Earth.

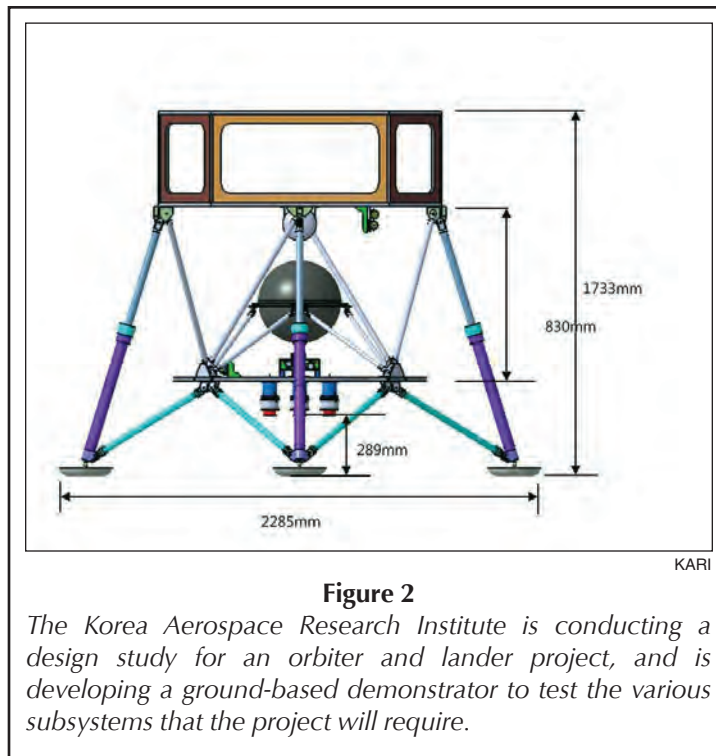


Figure 2
The Korea Aerospace Research Institute is conducting a design study for an orbiter and lander project, and is developing a ground-based demonstrator to test the various subsystems that the project will require.

Until last February, the next steps in Mars exploration to culminate in a sample-return mission, were the joint European-U.S. Exo-Mars 2016 and 2018 missions. After the U.S. withdrew its participation, the missions have been reworked into a joint European mission with Russia.

In the 2020 time frame, ESA has plans to team with the Russian Space Agency, for a Lunar Polar Sample Return mission, as a precursor to a more challenging Mars Sample Return mission later that decade. This mission comes under a framework of long-term cooperation between the two space agencies, and leverages the near-term missions planned separately by each.

As described at the Naples conference, the proposed Lunar Polar Sample Return is "a very complex and ambitious mission" with many technical challenges. It is to consist of different elements, including landers, rovers, sample collection capabilities, and rocket stages to return the samples to Earth. All of these elements must be landed in close proximity to each other,

and function together.

ESA will apply its experience from its 2016 and 2018 ExoMars missions, and its proposed 2018 Lunar Lander. The Russians will have completed their 2015 and 2016 Luna-Glob missions, and their 2017 Luna-Resours mission will verify many of the technologies needed for the sample-return mission, such as landing a large platform, acquiring samples, and *in situ* scientific analysis.

Where is the United States in this long-range plan?

The unconscionable cancellation of NASA's well-planned and systematic Mars exploration program

was followed more recently by the Congressional stupidity of cutting NASA's travel budget. As a result, half of the scientists from the Jet Propulsion Laboratory, which manages NASA's Mars and other planetary missions, were unable to attend the Naples Congress to present their papers. Similarly, the American Astronautical Society has *cancelled* its November annual conference, because NASA officials could not obtain the funds to travel to Pasadena.

The future is created by those who can imagine it. No space mission is done in the "here and now." One of the encouraging signs at this year's international conference was that one third of the participants were under the age of 35. They will see the future.

But space exploration "during a time of austerity" can quickly become no space program at all.

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