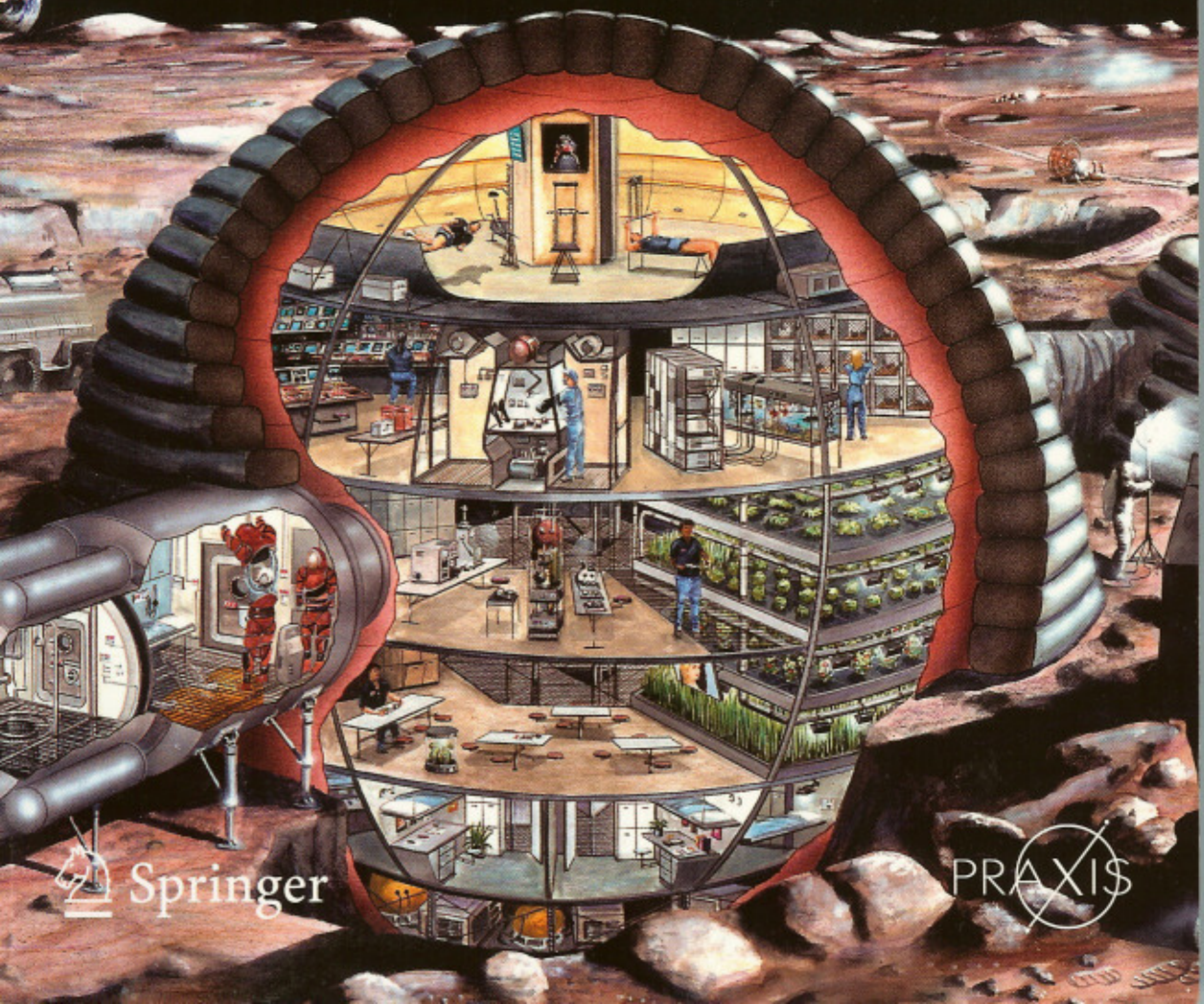
HAYM BENAROYA

TURNING DUST TO GOLD

Building a Future on the Moon and Mars



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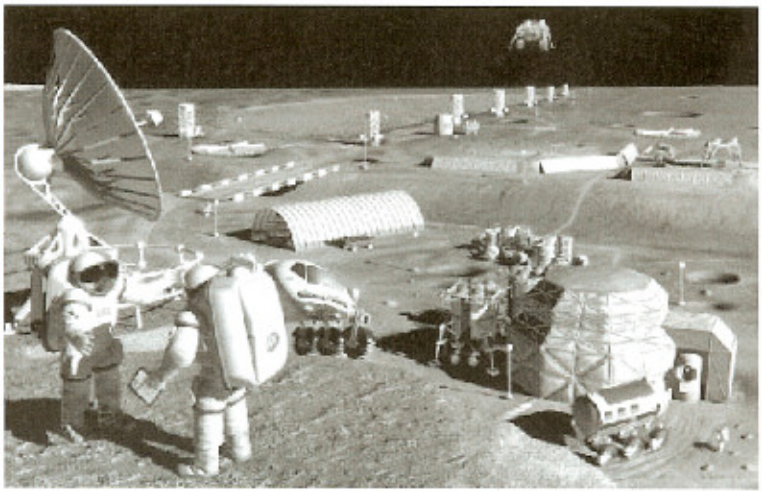

Fig. 11.1 Just a few kilometers from the Apollo 17 Taurus Littrow landing site, a lunar mining facility harvests oxygen from the resource-rich volcanic soil of the eastern Mare Serenitatis. Here a marketing executive describes the high iron, aluminum, magnesium, and titanium content in the processed tailings, which could be used as raw material for a lunar metals production plant. (This image was produced for NASA by Pat Rawlings, SAIC. Technical concepts for NASA's Exploration Office, Johnson Space Center, S99-04195, 1995. Courtesy NASA)

as a small organization that dealt with international contacts and the setting of space policies, it quickly took on increasing responsibility for the management of nonmilitary space activities and, as an added charge, aviation efforts. It was later renamed the Russian Aviation and Space Agency and then the Russian Federal Space Agency, commonly known as "Roskosmos", RKA, or RSA.

Russia has been a space powerhouse since the mid-20th century, with many scientific and engineering achievements – many matching and some surpassing those of the United States. Plans for the 21st century also included a return to the Moon, a return to Mars, new launchers, and numerous satellites and science missions.

Russia was a major player during the past almost 200 years of major space initiatives and has outposts as well on the Moon, Mars, and the key planetary bodies. The Russians are a part of all the entrepreneurial teams that have ventured forth in all directions from Earth.

The following historical interview recalls the Russian view of the Apollo era, and includes images of Russian concepts for advanced lunar cities.

11.1.1 An historical interview with Vladislav Shevchenko (June 2008)

Can you give us a one or two paragraph bio?

I have been Head of the Department of Lunar and Planetary Research, Sternberg State Astronomical Institute, Moscow University, Moscow, Russia since 1978. Previously, from 1964 I was at the Sternberg Astronomical Institute after graduating

from the Astronomy and Geodesy faculty. A candidate of Physics and Mathematics in 1969 and Doctor of Physics and Mathematics in 1982, I am a Professor at Moscow University, a planetary scientist currently investigating potential locations and designs for lunar and Martian bases. I participated in the creation of lunar and planetary maps and globes, and in astrophysical telescopic and space research of the Moon (the Zond and Lunokhod Soviet programmes, ESA mission SMART-1). I was involved in projects of the Soviet lunar manned base (during the 1970s to 1980s). Now I participate in the NASA project LRO-LEND[1] and in Russian projects PHOBOS-GRUNT[2] and LUNA-GLOB.[3] I have authored 215 papers and several books: *The Modern Selenography* (1980), *Observation of the Moon* (1982), *Lunar Base – Project of the 21st Century* (1989), *Lunar Base* (1991), and coauthored *Far Side Atlas of the Moon* (1967, 1975), *Optical and Thermal Parameters of the Moon* (2001), and *Model of Space* (2007).

What was the mood in the Soviet Union when Gagarin went into space?

Yuri Alekseyevich Gagarin was a Soviet cosmonaut. On 12 April 1961, he became the first person in space and the first to orbit the Earth. Of course, the mood of the Soviet people was enthusiastic. I remember all of the staff members of our organization (I was a student in that time) went to Red Square near the Kremlin in Moscow to celebrate with copies of Gagarin's photo that were cut from the newspaper. Figure 11.2 is the front page of the newspaper *Evening Moscow* from 12 April 1961.

In Figure 11.3 you can see a photo of such celebrations. The next picture (Figure 11.4) is very interesting. It's a photo from the newspaper *Evening Moscow* of 15 April 1961. This photo shows a meeting in the Kremlin. From left to right you can see Nikita Khrushchev, head of the Soviet government, Valentina Gagarina (Gagarin's wife), Yuri Gagarin, Nina Khrushcheva (Khrushchev's wife), Anastas Mikoian (one of the Soviet leaders in that time) and Sergei Pavlovich Korolev (!!!). It's very surprising. I believe it was the first and last example of the publication in the press of Korolev's photo. During all of his life he was a secret person. The quality of the photo is not good, but it's a copy from a real issue of the old newspaper from my collection.

What were the thoughts and feelings after the Kennedy Moon speech?

To my regret I don't remember. It seems to me that the Kennedy Moon speech was not published in the Soviet Union at that time. In any case, I learned about it later along with the Apollo flights.

In addition to Korolev, the Soviet counterpart to von Braun, who were some of the key people of the Soviet lunar effort? In what ways were these people special? What were their special talents?

[1]Lunar Reconnaissance Orbiter – Lunar Exploration Neutron Detector.

[2]Phobos-Grunt (soil) was an unmanned lander sent in 2011 by the Russians to study Phobos and then return a soil sample to Earth.

[3]Luna-Glob (sphere), an unmanned mission to the Moon sent by Russia in 2012 that includes an orbiter with ground penetrating sensors.


СОВЕТСКИЙ ЧЕЛОВЕК—
ПОКОРИТЕЛЬ КОСМОСА!
ВЕЧЕРНЯЯ
МОСКВА
СООБЩЕНИЯ ТАСС
СООБЩЕНИЕ ТАСС

Fig. 11.2 Photo of Gagarin on front pages of the *Evening Moscow* from 12 April 1961. (Courtesy Vladislav Shevchenko)

Fig. 11.3 Muscovites celebrating Gagarin's flight on 12 April 1961. (Courtesy Vladislav Shevchenko)

Fig. 11.4 Kremlin celebration of 4 April 1961. Photo from the *Evening Moscow* of 15 April 1961 shows a meeting in the Kremlin. From left to right you can see Nikita Khrushchev, head of the Soviet government, Valentina Gagarina (Gagarin's wife), Yuri Gagarin, Nina Khrushcheva (Khrushchev's wife), Anastas Mikoian (one of the Soviet leaders in that time) and Sergei Pavlovich Korolev. (Courtesy Vladislav Shevchenko)

Sergei Pavlovich Korolev (1907–1966) is widely regarded as the founder of the Soviet space program. The key people were the Council of the Chief Designers. In a photo from 1957 at the Baykonur Space Center (Figure 11.5) you can see the main members of the Council.

Of these Chief Designers, I knew Sergei Korolev and Valentin Glushko personally. According to my personal opinion, I believe that Valentin Pertrovich Glushko was the most talented specialist and space scientist. The engines designed by him were used to launch numerous Earth and Moon satellites and also to get aloft automated probes designed to head for the Moon, Venus, Mars, and send up Sputnik, Vostok, Voskhod, Soyuz, Proton, etc. Remember, on May 1961, President J.F. Kennedy said these words of the Soviet-built rocket engines: "We have come to witness that initial space achievements of the Soviet Union have been secured through the availability of high-power rocket engines, which has placed the USSR in the lead." In 1974, Glushko was appointed General Designer of the Energia Association. He was the leader of the Soviet lunar manned base project (1970s to 1980s). During that time he was the head of the group that created the Energia-Buran system.

Numerous previous test flights of the classic Soviet rocket R-7 (Sputnik, Vostok, etc.) were failures. All the test flights of the N-1 (lunar) super rocket were failures too. The very first test flight of Energia LV designed by Glushko was successful! The first test flight of the Energia-Buran space transportation system was successful too! The RD-107 and RD-108 rocket propulsion systems, created over four decades ago, continue to be functional in support of Russian cosmonautics, and they truly

Fig. 11.5 From left to right: Nikolay Alekseevich Pilugin (1908–1982) – Chief Designer of the control systems for rocket and spacecraft complexes; Sergei Pavlovich Korolev (1907–1966) – Chief Designer of the rockets and spacecrafts; Valentin Pertrovich Glushko (1908–1989) – Chief Designer of the rocket engines; Vladimir Pavlovich Barmin (1909–1993) – Chief Designer of the launch complexes (including the Baykonur space center). (Courtesy Vladislav Shevchenko)

can be dubbed "eternal" engines. The RD-108 is now stated to power the upgraded American Atlas LV.

The illustration from Gabon (Figure 11.6) is of Valentin Glushko, Sergei Korolev and Russian rockets created by different Russian designers; but all these rockets have Glushko's motors.

Is settling the Moon so important for civilization? How do we answer critics who say space is too expensive and that there are numerous problems on Earth to take care of first?

A number of ecological investigations and some results of paleoclimatology have found that the permissible level of energy production inside the Earth's environment is about 0.1% of solar energy received by the Earth's surface. This value is about 90 TW. On the other hand, the general prognosis shows that the total energy use (and production, accordingly) in the world will be about 16 TW soon after 2010. This value will increase by a factor of two (about 34 TW) by the year

Fig. 11.6 Gabon stamp depicting Valentin Glushko (top), Sergei Korolev (bottom) and Russian rockets created by different Russian designers. (Courtesy Vladislav Shevchenko)

2050. If this tendency continues, the total energy production in the world will approach 98 TW by the year 2100 (maybe by 2150). It means that the permissible level of energy production within the Earth's environment will be exceeded and the destruction of the Earth's environment will not be reversible.

But it is obvious that the processes destroying the Earth's environment on a global scale will begin before that time – after the middle of the century. It may be that we are now observing some of the signs of these processes as the global change of the Earth's climate and the unusual natural catastrophes in different regions of the Earth. Hence, our efforts to rescue the Earth's environment must see practical results no later than between 2020–2030 in order for the environment to survive.

The only way to resolve this problem consists in the use of extraterrestrial resources. The nearest available body – a source of space resources – is the Moon. The best known space energy resource is lunar Helium-3. Very likely, the lunar environment contains new resource possibilities unknown now. So, lunar research space programs must have priority not only in fundamental planetary science, but in practical purposes too. Now it's needed to consider the new lunar research space programs for practical purposes to rescue mankind in the 21st century.

Of course, space programs (and lunar manned settlements) are too expensive. However, this cost is not larger than the value of mankind!

What do you see as the major hurdles for our return to the Moon for permanent manned settlements?

I believe the hurdle is one: mankind does not understand that the current situation in Earth's environment is very tragic. About 10 years ago I tried to explain these problems to members of a commission of our parliament (State Duma) – in that time I was a member of an expert group on space sciences. The reaction to my speech was: "You try to frighten us to give money for your science." That was 10 years ago! Now we know that global changes of the Earth's climate and the unusual natural catastrophes in different regions of the Earth are realities. But I am not glad about my rightness! Many people think now as we did 10 years ago.

Fig. 11.7 Valery Vladimirovich Polyakov spent 438 continuous days aboard Mir, from 8 January 1994 to 22 March 1995. (Courtesy Vladislav Shevchenko)

Are human physiological and psychological factors being taken as seriously as the engineering factors in the return to the Moon? Given the numerous hours spent by Russians in space, are you confident that we know enough about human physiology in low gravity and under space radiation to assure astronaut safety on the Moon for extended periods of time?

It seems to me that the activity of astronauts and cosmonauts in space during many months provides as a basis for extended stays for man on the Moon. Valery Vladimirovich Polyakov (born in 1942), a medical doctor (Figure 11.7), spent 438 continuous days aboard the Mir orbital station. Additional modules of the station that housed scientific equipment and expanded the living space were attached to Mir in subsequent years.

When you envision human settlement of the Solar System, where do you see us in 50 years? In 100 years?

The following chart shows my estimates for the proposed time-line for lunar industrialization:

Stage	Years
Deadline for mankind to colonize the Moon	2100–2150
Space power and lunar resources utilization	2040–2050
Initiation of space industrialization	2020–2030
Preliminary elaboration and appraisal	2010
Principle decision	yesterday

The table gives the proposed stages for the creation of a space industrial system during the century from the future critical date ("deadline for mankind") to the present. If destruction of the Earth's environment is to be reversed by the end of the century, the first results of the practical actions taken to rescue the environment must be observed no later than during the 2020 to 2030 time frame. It means that general decisions to return to the Moon must be approved now – at the beginning of the century.

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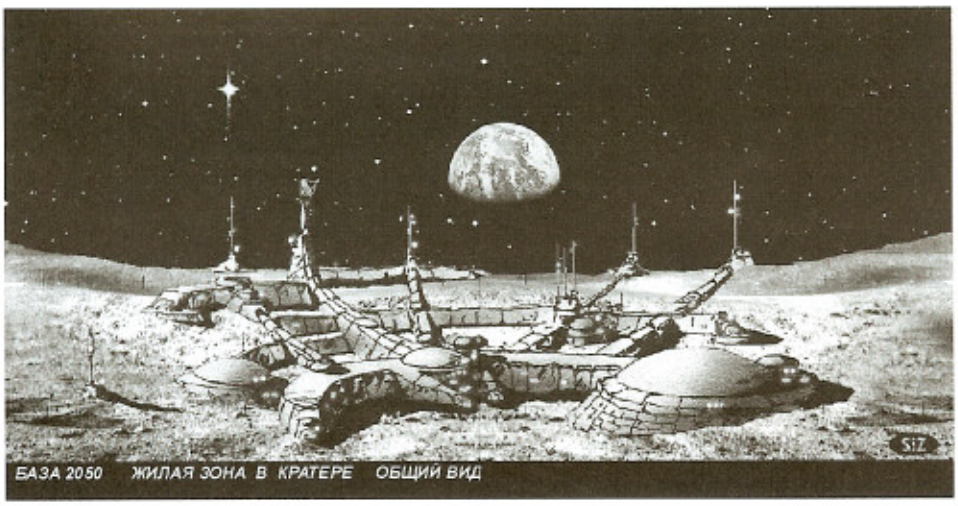

Fig. 11.8 Manned Lunar Base 2050: Energia-Sternberg Project, residential zone in crater, general view. (Courtesy Vladislav Shevchenko) See Plate 13 in color section.

By the present-day – in 2169 – the majority of our facilities are under the lunar surface. It was known very early on that once we had the infrastructure in place we would be excavating and erecting our facilities under regolith – especially the habitats. If you were to be taking a Sunday drive on the lunar surface around our

cities, you would only see occasional towers and antennae protruding the surface, perhaps a few low-lying buried structures.

The Russian concepts from the early 21st century presented on these pages are representative of such structural expanses. We are not laid out in exactly the same way, and we were nowhere near such complexes in 2050, as depicted in the images.

A base in a crater is shown in plan view in Figure 11.9 and in side view in Figure 11.10. There are inhabited modules (1), clean room facilities (3), rehabilitation centers (5), medical facilities (6), a control center (7), and laboratories (10).

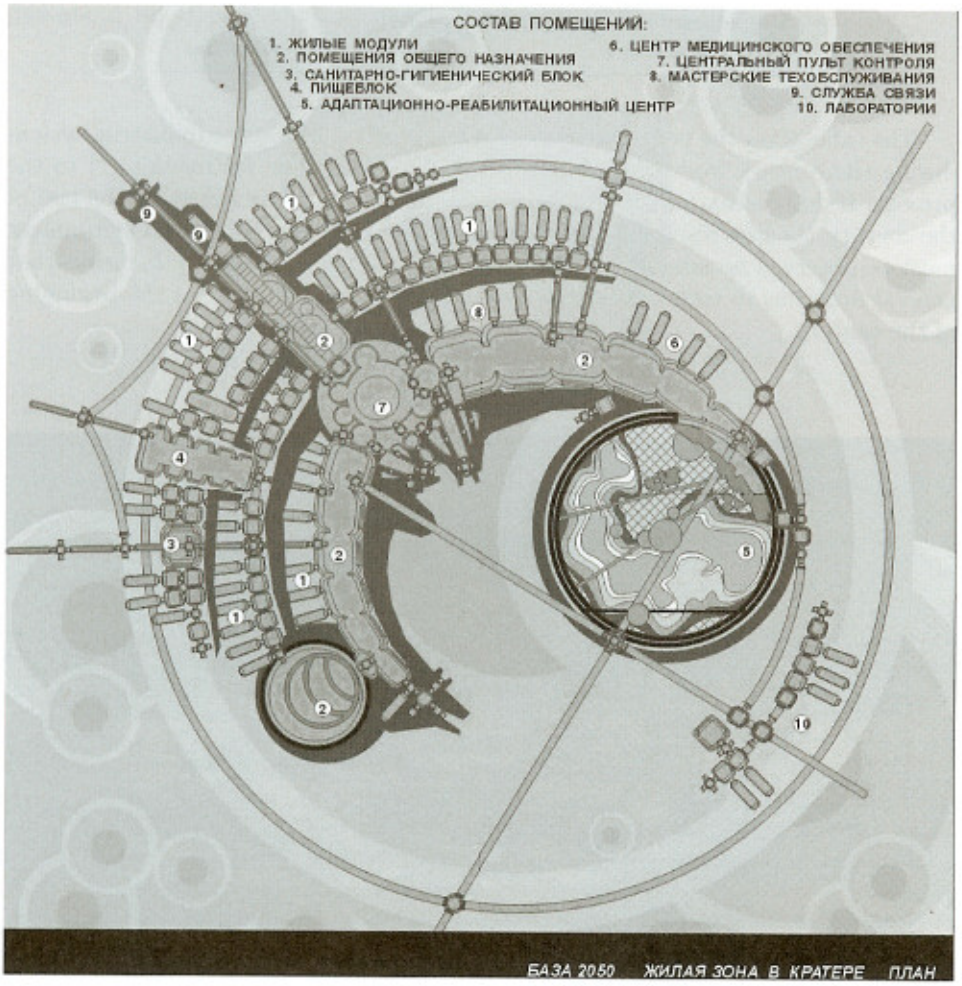

Fig. 11.9 Manned base in crater: plan view. **Legend:** 1. inhabited modules 2. general purposes 3. clean facilities 4. kitchens 5. adaptation and rehabilitation 6. medical facilities 7. control center 8. maintenance 9. communications 10. labs. (Courtesy Vladislav Shevchenko) See Plate 14 in color section.

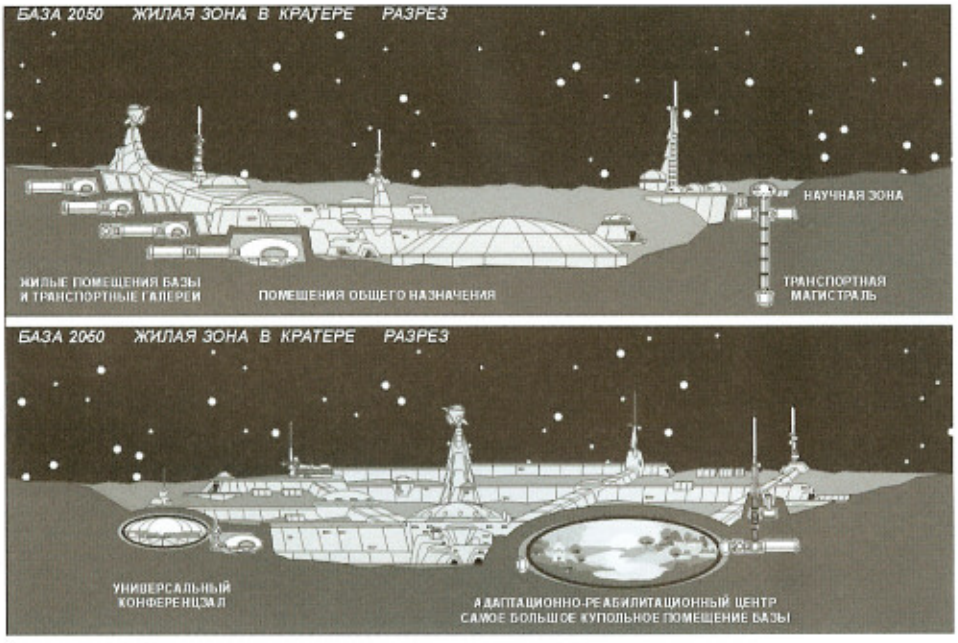

Fig. 11.10 Manned Base in Lava Tube. Energia-Sternberg Project. Side Views. The base is mostly within the lava tubes for shielding. In the top figure: on the left side are general purpose premises; the lower left are residential facilities; on the right side is the scientific zone and a transport line. In the bottom figure: in the lower left is a general conference hall, and in the lower right side is a rehabilitation center and the largest cupola-shaped premises on the base. (Courtesy Vladislav Shevchenko)

The rehabilitation facilities (5) are quite remarkable. In an ellipsoidal volume we have what looks like a small town with trees and a body of water. In this concept drawing, technologies have been assumed to permit the containment of the water. The volume is lit by natural light. This must be where it was conceived that the inhabitants of the lunar settlement go to rest and decompress.

Lava tubes were considered to be prime locations for large lunar settlements, providing a natural defense against radiation, temperature variations and micrometeorites. Figure 11.11 depicts an advanced concept, shown from three perspectives and at different levels of detail. In the present day we have buried facilities, but nothing so extensive.

The Japanese have been a prime mover when it came to technology development for the return to the Moon and for allocating the resources necessary to make it happen. They have worked with the United States and Korea in support of the Bush Vision of 2004. Here on the Moon, in 2169, the Japanese are embedded in the life of the settlements in all ways, from research to commerce. They are also major participants in our solar power generation efforts as well as the nuclear fusion developments.

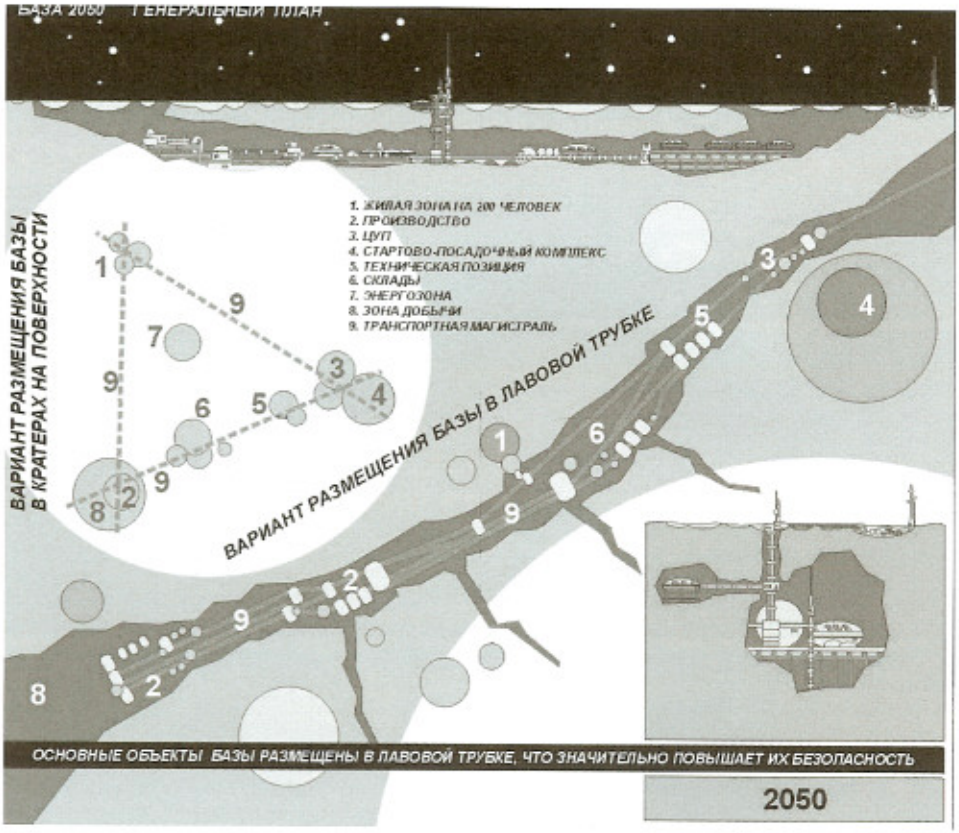

Fig. 11.11 Manned Base in Lava Tube. Energia-Sternberg Project. The base is mostly within the lava tubes for shielding. **Legend:** 1. residential facilities for 200 people 2. manufacturing 3. control 4. launch complex 5. technical 6. warehouses 7. power systems 8. shelters 9. roads. (Courtesy Vladislav Shevchenko)

11.2 Japanese concepts

On 1 October 2003, the Institute of Space and Astronautical Science, the National Aerospace Laboratory of Japan and the National Space Development Agency of Japan (NASDA) were merged into one independent administrative institution: the Japan Aerospace Exploration Agency (JAXA). While space development and utilization, and aviation research and development are the measures to achieve the nation's policy objectives, JAXA's corporate message is "reaching for the skies, exploring space," while contributing to the peace and happiness of humankind.

11.2.1 An historical interview with Hiroshi Kanamori (April 2009)

Can you give us a one or two paragraph bio?

I was born in January 1958 and majored in concrete material engineering at Waseda University. After finishing the post-graduate school of Waseda, I began to study

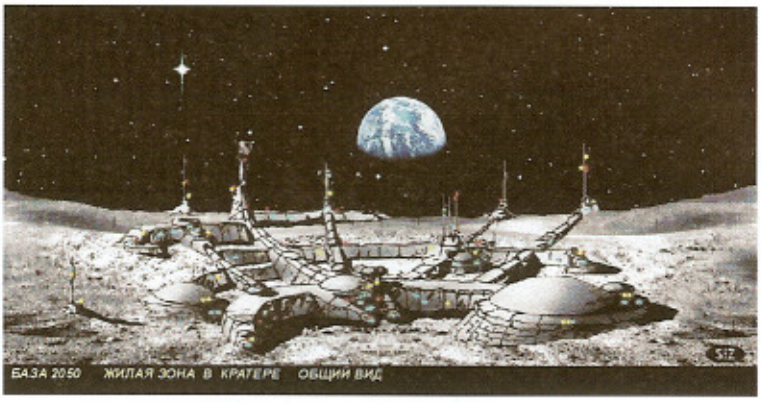

Plate 13 Manned Lunar Base 2050: Energia-Sternberg Project, residential zone in crater, general view. (Courtesy Vladislav Shevchenko) See Fig. 11.8 on page 353.

Plate 14 Manned base in crater: plan view. **Legend:** 1. inhabited modules 2. general purposes 3. clean facilities 4. kitchens 5. adaptation and rehabilitation 6. medical facilities 7. control center 8. maintenance 9. communications 10. labs. (Courtesy Vladislav Shevchenko) See Fig. 11.9 on page 354.