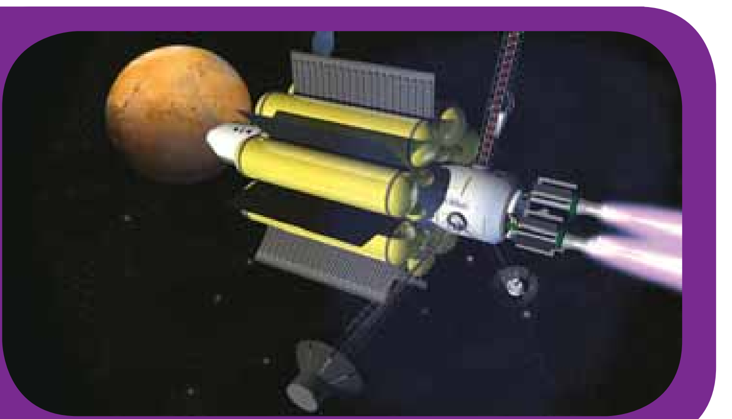
Mars: The Next Fifty Years

by Marsha Freeman



KEPLEROPOLIS, July 20, 2059 —Today is a day of joyous celebration on Mars. As the citizens of Kepleropolis look back 90 years, to commemorate the historic first steps of human explorers on the Moon, their eyes are fixed on the imminent launch of their newest spacecraft, Kepler II. This will be the first craft to use the revolutionary new, and still-experimental, antimatter propulsion system. If successful, the spacecraft will reach neighbouring stars, comfortably within the lifespan of the scientists who are anxiously awaiting the discovery of new worlds. There is great excitement that Kepler II will open up the universe to mankind, just as 90 years ago, Apollo opened up the Solar System.

While Kepler II will not be carrying a human crew, its mission is to visit Earth-like planets orbiting distant stars, once thought to be impossible to reach in a human lifetime. Over its five-year mission, its predecessor, Kepler I, launched into Earth orbit in March 2009, had identified hundreds of target solar systems to explore. Johannes Kepler (1571-1630), who determined the laws of our Solar System, would undoubtedly be pleased that our scientific instruments will soon be looking for planets around other stars.

While everyone in Kepleropolis is anxiously awaiting today's Kepler II launch, pausing to follow the minute-to-minute progress of the launch preparations on large screens placed throughout the city, researchers working in the Advanced Propulsion Laboratory are especially anxious.

The revolutionary new anti-matter propulsion drive that will take Kepler II to the stars began its development more than 20 years ago on Earth. But it was brought to realization by a scientific team working in the Lab in Kepleropolis. Now it was time see if the system could deliver.

Just as those who came before them nervously watched the first satellite launch, in 1957; the first manned mission, in 1961; the first human footsteps on the Moon, in 1969; and the first manned landing on Mars, in 2048, these young pioneers paced back and forth, waiting for lift-off.

Finally, the moment arrived, chosen to coincide exactly with Neil Armstrong's first step onto the Lunar surface, now almost a century earlier. The booster engines ignited, and Kepler II was easily carried aloft. Once in Mars orbit, the anti-matter drive sprang to life. Kepler II was on its way to discover new Earths.

Very few people living on Mars today were alive when Neil Armstrong spoke those first words from the surface of the Moon. But no one here can forget on whose shoulders he stands. However, what *is* very difficult for citizens of Kepleropolis to understand, especially those who did not witness or participate in the Second American Revolution of 2010, is how it was that so many decades could have been wasted.

For years after the abrupt end of the Apollo Program in 1972, space enthusiasts would lament that it would take a crisis, like that faced by President John F. Kennedy in 1961, to goad an administration in Washington to make the commitment needed for a visionary, multi-decade program to move human civilization into space. That crisis came in the Fall of 2009.

Perception finally caught up with reality. The global financial house of cards, based not on any physical economy, but on criminal enterprise, speculation, and outright stealing, in order to "make money," finally collapsed. Commerce, production, and life itself came to a standstill. Here was the opportunity to start over, sweep away decades of pessimism and failed policies, and return to the principles which today, on Mars, seem like common sense. The revolution began by "exorcising" the worship of money.

Starting Over

A series of global, credit-based international exchange-rate and trade agreements was quickly concluded, reflecting back to the policies of U.S. President Franklin Roosevelt, and initiated by economist Lyndon LaRouche, who had proposed a four-power agreement among the U.S., Russia, China, and India. Through this arrangement, each nation could contribute to the restart of the overall global economy.

One immediate task was turning what could have been an ugly, violent mob-reaction to the collapse, and descent into a New Dark Age, into a renewal of the letter and spirit of the first American Revolution.

Great projects of infrastructure building got underway on Earth, in the footsteps of the first U.S. Treasury Secretary, Alexander Hamilton, who had designed and implemented the credit policies that built the economic infrastructure of a young United States. The first task in 2010, was the rebuilding of a planet devastated by disease, starvation, and war, and to reverse the decades of accumulated physical decay.

But as space visionaries insisted at that critical moment, only a multi-generational great project could challenge and mobilize the long-dormant creative resources of the human mind. The scientific discoveries of such a project would unleash the next revolutionary generations of technology, and drive economic growth on Earth.

The politicians reluctantly came to agree. And so, in that spirit, the project to build a science city on Mars came into focus. The cultural pessimism that had taken hold in the late 1960s, and kept its grip on much of the world's population for 50 years, began to disappear.

In fact, the natural optimism of humanity had not been extinguished during the dark decades of economic decline, only submerged. With the focus now on the future, socially anomic video games, "reality" television, fixations on sex, violence, and "competitive" sports, and a "culture" of death had no place. Mankind would, once again, find its true nature, in the process of discovering the secrets of the universe. The question posed to every citizen of the world was: What can you contribute to the future of mankind?

And so it was decided, in early 2010, by nearly all of the nations of the world, that through a coordinated effort, enlisting the necessary talents of all of mankind, within 50 years, human civilization would move to Mars.

Living on Mars

From the start, moving humanity to Mars had as its central purpose the ability to acquire a greater understanding of the universe, by creating a multi-planet home for humanity. For this reason, scientists explained, there could be no thought of trying to "save money," by setting up an outpost, or an Antarctica-like basecamp on the Red Planet. A science city was designed, with a sufficiently large population, which is now approaching half a million, to support not only the scientific staff and facilities of Kepleropolis, but, eventually, to create an independent new world, as the jumping-off point for developing the further reaches of the Solar System.

Scientists and engineers were optimistic that they could solve the technical challenges to get man to the outer planets. But medical professionals were not convinced that men and women could safely *live* there. They were unsure of how the human body would adjust to the one-sixth gravity of the Moon, or, later, the one-third gravity of Mars.

Kepleropolis, the city on Mars. The centre hub is the scientific, cultural, and educational focus of the city, with museums, universities, laboratories, theatres, and other cultural centres. In the next ring are the residential areas; and beyond, industrial and agricultural facilities. In 2059, there are nearly a half million residents on Mars. Christopher Sloan

Would colonists be able to return to the 1-gravity environment of Earth? they asked. They knew, through previous studies in microgravity, that after six months in weightless Earth orbit, some crew members had lost up to 30% of their bone mass. Even after two years of recuperative therapy on Earth, some space travelers did not recover completely. Would the same debilitation face residents living in the fractional Earth-gravity on the Moon and on Mars? Would they leave Earth, unable to return? These questions had to be answered, before more than a few brave souls would volunteer to go.

In order to find answers, research on the Space Station, to determine the physiological effects of partial-Earth gravity, was, therefore, greatly accelerated in 2012. Two years earlier, the European and Japanese space agencies had decided to deploy, as quickly as possible, a centrifuge to the Station. The centrifugal force created through the rotation of the centrifuge would mimic variable gravity levels, depending upon the rate of rotation.

There had been much hand-wringing years earlier, when NASA cancelled the Japanese-built centrifuge that had been developed for the Space Station. Subsequently, a crash program was undertaken, and a small, yet capable centrifuge was doing partial-gravity tests by 2012.

Medical professionals had observed, through data collected on the 1970s U.S. Skylab station, the Russian Mir station in the 1990s, and the International Space Station (ISS) in the early 21st Century, that some physiological changes, such as the loss of bone mass, appeared to be continuous, throughout a stay in micro-gravity, while other changes reached a plateau. But would this be the case in the partial gravity environments of planets?

Centrifuge studies on the Space Station, from 2012 on, indicated that the one-sixth gravity of the Moon did not reach the threshold of load on the musculoskeletal system, in particular, to prevent deterioration.

However, from carefully studying films of the Apollo astronauts cavorting on the surface of the Moon, medical specialists determined that when the weight of the 200-pound space suit was added to the weight of the NASA astronaut, the gravitational load on the skeletal system could prevent serious bone loss.

But for those who were not outside the spacecraft, some reconditioning was necessary, after long stays on the Moon, if the Lunar inhabitant wished to return to Earth.

For decades, scientists had worked within their different medical specialties to find preventive and palliative measures to combat each one of the body's adjustments to microgravity. But this approach left the traveler ingesting a pharmacy-worth of drugs, sometimes with counteracting effects, and spending many boring hours on treadmills.

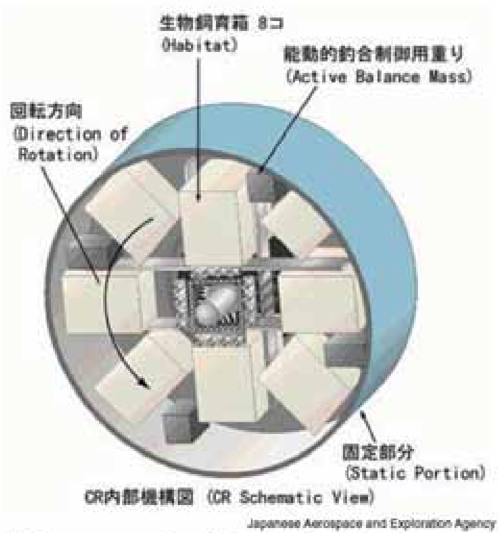
Then, about 20 years ago, it dawned on the engineers who were developing new exercise equipment, that before returning to Earth, orbital and Lunar citizens could combat just about *all* of the debilitating effects *at once*, by simply spending time in a variable-gravity Lunar centrifuge!

Scientists followed their lead. They reported the results of their experiments, carried out at the Gauss University Laboratory for Advancing Human Health on the Moon, to an interplanetary teleconference of medical specialists in mid-2041. They had found that over a period of weeks, by incrementally raising the gravitational load on the body in a centrifuge, through relatively short doses throughout the day, immune system reactivity, bone and muscle strength, heart function, and other physiological systems gradually approached a level comparable to that on Earth.

Happily, follow-on partial-g studies, in centrifuges on the Space Station and on the Moon, revealed that, in all but the most intractable cases, such as bone thinning and calcium loss, the one-third gravity of Mars was *above* the threshold for most physiological changes. As mission planners, back to the 1950s, had hoped, extended stays on Mars would create no "show-stoppers" for a return to Earth. But, as a precaution, still today, travellers planning a vacation or a business trip to Earth, spend a couple of weeks in short, periodic sessions in the variable-g centrifuge, for a 1-gravity

Even though astronauts spent hours per day exercising while in orbit, they still experienced musculoskeletal deconditioning in microgravity. The effects were not always fully reversible, once back on Earth. Here, U.S. astronaut, Shannon Lucid, is exercising on a treadmill during her record-setting 188-day stay on the Russian Mir space station, in 1996. NASA

As an Apollo 15 astronaut descends from the Lunar Module to the surface of the Moon in the Summer of 1971, his 200-pound life support backpack clearly is visible. Although the added weight has been found to counter some of the effects of the Moon's only 1/6 Earth's gravity, scientists found there is still a need for some reconditioning, before return to Earth. NASA



Japanese Aerospace and Exploration Agency

This Japanese centrifuge design was planned for the International Space Station. The habitats are small modules designed to hold seeds, plants, microbes, or small animals. Depending upon the speed of rotation of the centrifuge, partial gravity at the level found on the Moon and Mars can be simulated.

Space visionary Krafft Ehricke proposed that the disabling effects of adaptation to microgravity could be therapeutic for people on Earth. In this photo, taken in the CBS-TV studio in September 1966, he is explaining to journalist Walter Cronkite (r.) how an orbital hospital could be designed. Courtesy of Krafft Ehricke

"tune up," under the guidance of the Kepleropolis medical staff.

Multi-Planet Families

However, there is one adaptation problem still under intensive study in the Life Sciences Laboratory in Kepleropolis. It has been observed that children born and raised on Mars do exhibit physiological changes (they are taller), but apparently do not develop the capacity to withstand an Earth-equivalent gravity load. The skeletal system, which develops on Earth under weight-bearing gravitational stress during childhood, has diminished load capacity on Mars. Although some palliative measures are being tested, none has proved to be satisfactory. So, for now, multi-planet family reunions take place on gravitationally "neutral" ground, such as in Lunar or Mars orbit.

All of these experimental results have, of course, been shared with colleagues on Earth. In late 2018, after new laboratory modules, more advanced equipment, nuclear power supplies, and six additional crew members had been added to the ISS, a proposal that had been made in the 1960s by space visionary Krafft Ehricke, came to fruition.

It had occurred to Ehricke that the adaptation to microgravity which was detrimental to the health of Earth-returning crew members, could be *therapeutic* to whole groups of people, for whom Earth's 1-gravity was a burden. This included those suffering from circulatory ailments, where the removal of gravity could lessen the workload for the heart.

Spinal extension, or a stretching out, seen in micro-gravity (crew members tend to "grow" an inch or two in space), when gravity-induced compression is removed, could relieve the pain of pinched nerves, and chronic bone conditions, Ehricke reasoned. And so, the Earth-orbital Michael DeBakey Memorial Hospital was built, with a complete physical therapy wing, along with a dispensary and clinic to treat on-orbit sickness and injuries from accidents. Similar facilities were replicated in Lunar orbit.

Life in microgravity meant that many of the physical infirmities of old age were no more. The Earth-orbital population grew by leaps and bounds, as seniors moved out of nursing homes on Earth (which, in any case, had become more like hospices, where people were sent to die), and took up residence where they could live comfortably and work productively, while looking down at their home planet, from 250 miles up.

But there was one very serious and potentially life-threatening biological hazard in space that was not so easily resolved: exposure to radiation.

In low-Earth orbit, the Van Allen belts deflect harmful radiation, protecting crews. And on planetary bodies, there is no lack of material to shield people, plants, and animals from the constant bombardment of cosmic rays and solar particles and radiation. The first extraterrestrial living quarters were simply covered with Lunar and Martian soil. More recently, new materials have been developed to blanket the cities, which can filter out damaging rays, while letting in natural light.

But what about the radiation that crew members would be exposed to during the trip to Mars, navigating through up to 50 million miles of radiation-soaked interplanetary space? Medical professionals had fretted over this danger for decades. Technologists had spent long, tedious hours in laboratories, trying to figure out how to put radiation shielding around a spaceship to protect the crew.

The solution, however, was much simpler: avoid exposing the travelers to dangerous doses of cosmic radiation, by getting to Mars as quickly as possible.

Getting to Mars

Today, families of vehicles navigate the ocean of interplanetary space around the clock, traveling between the Earth, the Moon, and Mars. Only a few miles from downtown Kepleropolis is the Interplanetary Space Launch Centre. The space port is responsible for coordinating the vehicles arriving and departing the Red Planet, similar to the function of a busy airport on the Earth.

Once a month, for example, a spacecraft arrives from the vicinity of the Earth or the Moon, delivering astronomers who will carry out studies of the universe from the unique vantage point provided by the Mars-orbital radio and optical telescopes. There are frequent exchanges of scientists, who study the anomalies among the astronomical observations made from different vantage points, near the Earth, the Moon, and Mars. Of course, there are also business trips, and recreational and family visits.

What made this routine personal contact between the planets possible? It was changing the relative relationship between space and time. Conventional rockets bring people to Earth-orbit in eight minutes and to the Moon in two days. Extend that technology to Mars, and the trip could take seven or more months. But today, to traverse the tens of millions of miles to Mars, takes the same time as it does to go to the Moon! (See: http://larouchepac.com/files/onehohmanntwoaccelerating.flv.)

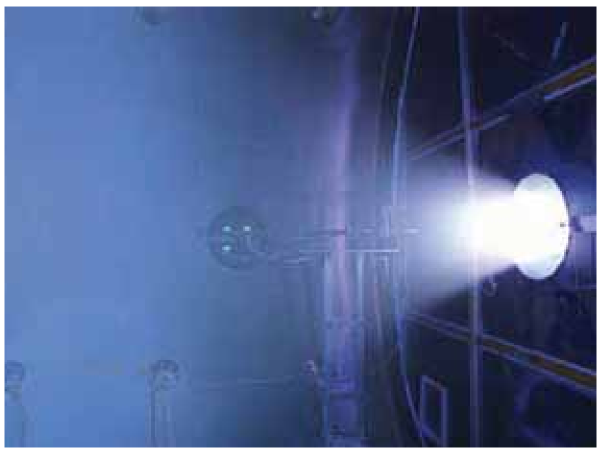
The development of a fusion-powered plasma rocket has reduced the travel time between Earth and Mars to less than a week. No longer would doctors have to worry about subjecting crews to weeks, or months, of damaging radiation, or the debilitating effects of weightlessness.

The creation of the fusion rocket can be largely credited to the talent and perseverance of Dr. Franklin Chang-Diaz. A former astronaut and plasma physicist, Chang-Diaz was convinced, from the time he was a researcher at MIT in 1979, that the only way to go to Mars was to go beyond the chemical rocket propulsion technology that had been used for 50 years. Mars travel required something in an entirely new physical régime—a plasma rocket that could one day be powered by fusion energy.

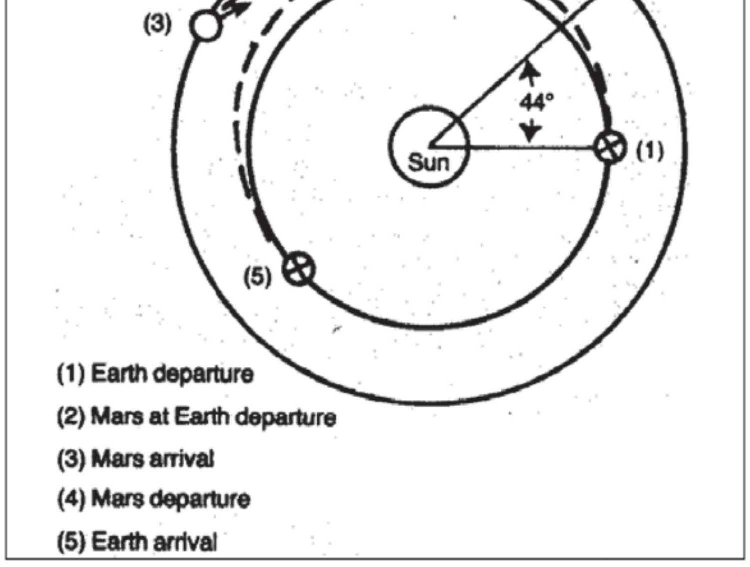
Chang-Diaz established the Advanced Space Propulsion Laboratory at the Johnson Space Center in Houston, in 1993, and started on what became a multi-decade quest to develop the technology mankind would need to go to the planets. Scientists pooh-poohed the project. "Everyone knows fusion power is impossible," some muttered. "And even if it weren't, you will never design a rocket that can use it."

The team that Franklin Chang-Diaz assembled, including his younger brother in Costa Rica, spent 30 years finding a solution to the challenge of designing a system that could withstand the temperature, in the *millions* of degrees, of a fusion plasma, and transform it into propulsive thrust for a rocket.

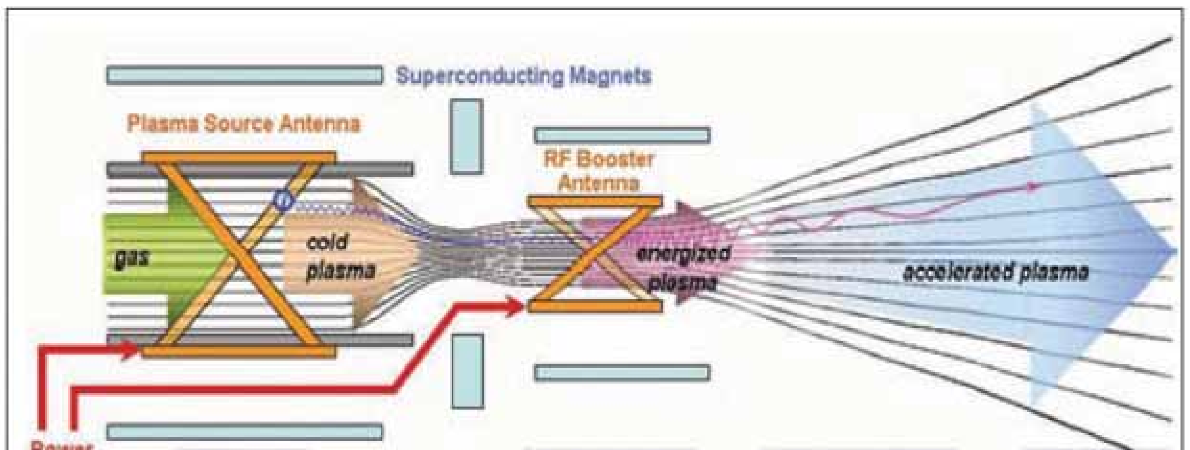
Astronaut and plasma physicist Franklin Chang-Diaz is seen here during flight STS-46, aboard orbiter Atlantis, in August 1992. NASA.



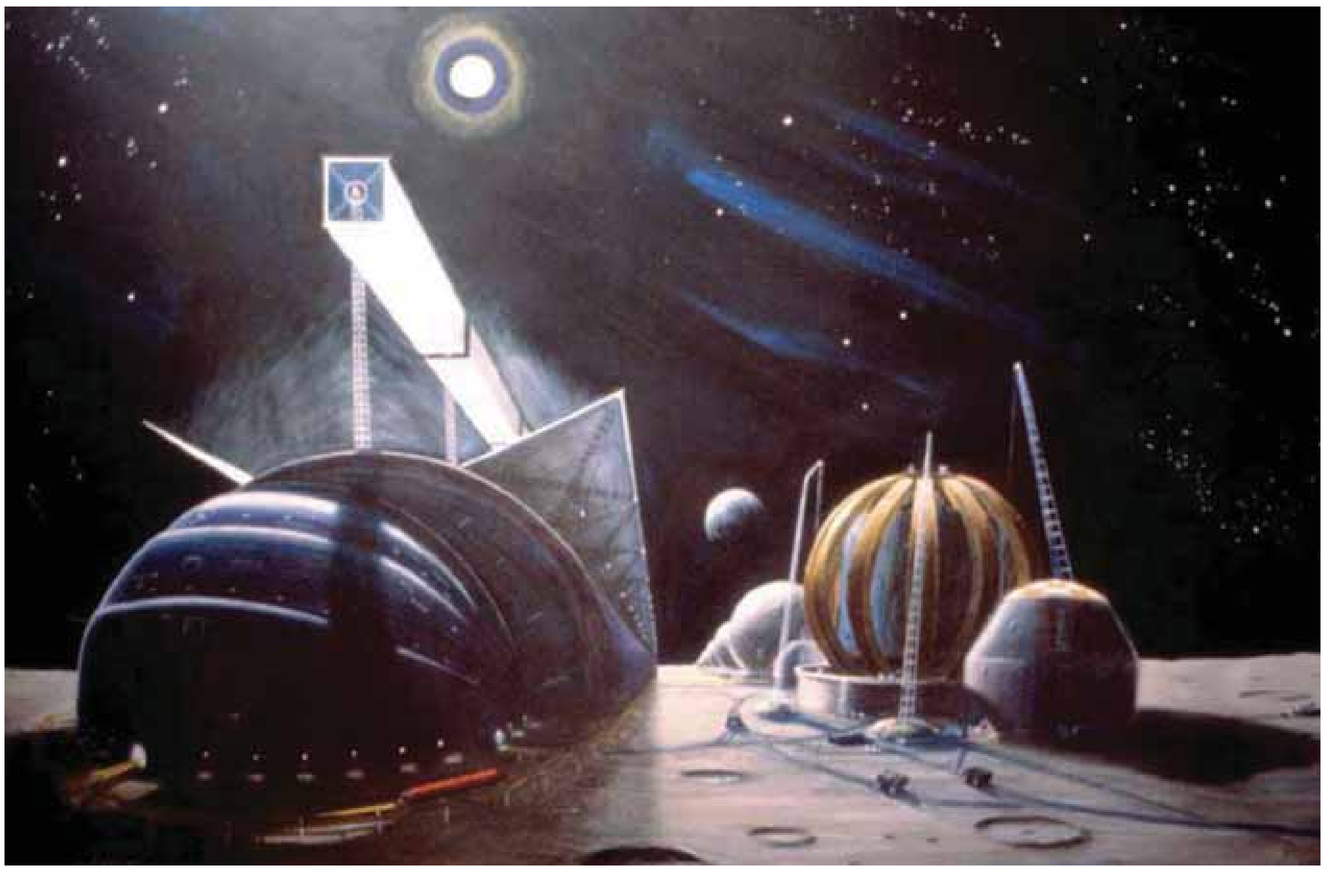
This image is from a video of a laboratory test in July 2009, of the first stage of the VASIMR plasma rocket. That stage heats a gas to over 10,000°, creating a plasma. Chang-Diaz plans to test a small VASIMR engine on the Space Station in the next few years. Ad Astra Rocket Company



In 1925, Walter Hohmann designed the minimum energy transfer orbits shown here. The crew starts out when Earth (1) is 44° ahead of Mars (2), and intersects Mars in its orbit (3), having traveled about 250 days. After spending more than a year on Mars, the craft leaves Mars orbit (4) and arrives back on Earth, another 250 days later, at point (5). Fusion magazine



The VASIMR rocket is made up of three principal stages: 1. a gas is ionized; 2. the plasma is energized and accelerated; and 3. the plasma is detached from the rocket by a magnetic nozzle. The nozzle directs the exhaust, to produce thrust. Ad Astra Rocket Company



Selenopolis, Krafft Ehricke's city on the Moon, seen here in an artist's depiction, is the first triumph of human creativity and imagination in the colonization of space. The city, housing thousands, is powered by fusion reactors, seen under construction on the right. Although Selenopolis is covered with lunar soil, to provide shielding against radiation, a series of mirrors brings natural sunlight in to the city. A monorail system, seen on the outer rim of the city, connects it to mining and manufacturing sites on other parts of the Moon. Christopher Sloan

The Australian University of Queensland Hypersonics Initiative has produced impressive results testing engines that reach speeds of more than five times the speed of sound. This June 2007 HyCAUSE test was a collaborative effort, with the U.S. Department of Defense. University of Queensland

Why Fusion?

When it comes to rocket propulsion, the hotter, the better. The efficiency of the rocket engine increases, as the temperature and velocity of the propellant pushed out the rear increases. And the energy produced by the fusing of light ions is orders of magnitude higher than that of any other energy source that has so far been developed.

For comparison, the temperature of the propellant expelled by the 1980s Space Shuttle's main engine, from the chemical combustion of hydrogen and oxygen, was about 14,000° Centigrade. At that temperature, the exhaust velocity is about 4,500 meters per second. The fusion-powered plasma, in the millions of degrees, is about 60 times more efficient, as the plasma particles can move at velocities of 300,000 meters per second.

Chang-Diaz designed the VASIMR, for Variable Specific Impulse Magnetoplasma Rocket. The concept was based on the use of a plasma, or high-temperature electrically charged gas, instead of the burning of chemical fuels. The first-generation engine consisted of three cells, or stages.

In the first stage, a gas, such as hydrogen, is turned into a plasma, by heating it to more than 10,000°. At that point, the electrons are stripped away from the atoms.

In the second stage, the plasma gas is heated to the desired temperature, using electromagnetic radio waves. The third stage—the most challenging—is to coax the plasma out of the rocket engine, to create a plasma exhaust, and rocket thrust. To do this, VASIMR takes advantage of the fact that the electrically conducting plasma can be directed by magnetic fields. A unique magnetic nozzle was developed, to direct the flow of the hot plasma out of the engine, without touching the sides of the nozzle.

What makes this engine "variable"? The amount of thrust produced can be changed by varying the amount, and weight, of the gas that is being expelled, as well as the strength of the magnetic field which directs the plasma. At the start of an interplanetary trip, more, or heavier propellant will be used, to give the spaceship the thrust it needs to start on its journey, and pick up speed.

Once the appropriate speed is reached, the engine can be "throttled back" to lower thrust levels. This is done by reducing the mass of the plasma exhaust, while increasing the velocity of the exhaust particles. The higher exhaust velocity is the most fuel-efficient operating mode. By "tuning" the fusion-powered ship, its acceleration is variable.

This capability turned out to be critical, when, six years ago, a ship that suffered a serious mechanical breakdown mid-way to Mars, had to abort the mission and quickly return to Earth.

As the crew approaches the halfway mark, the spacecraft will start its *deceleration*, so it can approach the orbit of Mars, and dock with one of the Mars-orbital space stations. From there, small shuttle vehicles easily transport the passengers to the surface of the planet.

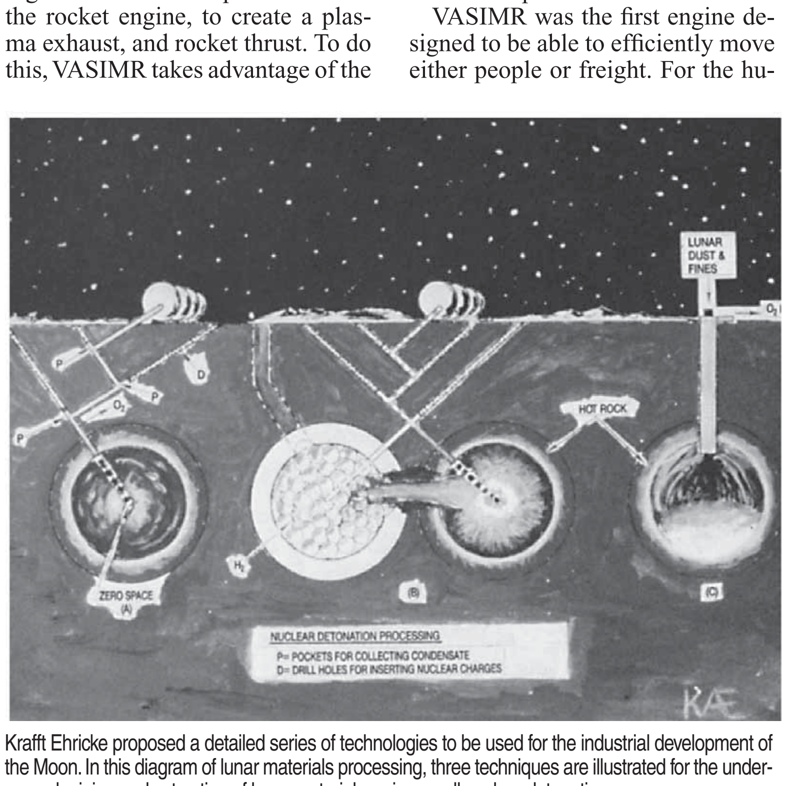
VASIMR was the first engine designed to be able to efficiently move either people or freight. For the human trips to Mars, clearly, time was of the essence, so, for human transport, the VASIMR engine was energized with fusion power, and operated to optimize speed.

But to build Kepleropolis, thousands of tons of equipment, life-support systems, and structural materials taken largely from the Moon, but also from Earth, had to be transported to Mars. In this case, it was not speed, but cargo-capacity that was optimized.

Dr. Chang-Diaz began his laboratory ground testing years before fusion energy was available. The first stage of the experimental rocket engine, and of the second-stage radio frequency plasma heating, were successfully tested during the Summer of 2009 (see: http:// www.onorbit.com/node/1276). In 2012, a first flight version of the VASIMR was ready to be tested in space, on the Space Station. The test engine used the Station's electrical supply for the kilowatts of power needed to heat the plasma. The small thrust produced was even used to boost the Station into a slightly higher orbit.

Parallel to the development of the plasma rocket technology, there was a crash effort to develop a multimegawatt space nuclear fission plant. This technology had shown great promise decades earlier, but had been abandoned in the early 1970s, in the United States, when there was no plan to go to Mars, and in the early 1990s in Russia, after the collapse of the Soviet Union.

In 2030, a revolutionary 200 MW nuclear-powered VASIMR rocket got its first test run in Earth orbit. The nuclear energy source used was an improved version of the Russian Topaz reactor from the 1990s. Just four years later, nuclear-propelled cargo ships were making regular runs between the orbits of the Earth and the Moon. Not long after that, ships were delivering cargo from the Moon's orbit, to that of Mars—in only 39 days. Interplanetary commerce had become a reality.



Krafft Ehricke proposed a detailed series of technologies to be used for the industrial development of the Moon. In this diagram of lunar materials processing, three techniques are illustrated for the underground mining and extraction of lunar materials, using small nuclear detonations. Fusion Magazine

A Worldwide Effort

Dr. Chang-Diaz's VASIMR plasma rocket was, by no means, the only fusion design tested, nor is it the only one flying today. A broad-scale research and development program was restarted in 2010, to apply fusion to power space travel. A major contribution to the international fusion effort came from the stunning results China and South Korea had already achieved.

Every nation was called upon to contribute to space transportation infrastructure. For instance, Australia, where a band of young university enthusiasts had taken the lead, in the early 21st Century, in hypersonic engine testing, developed a family of transatmospheric vehicles, that could efficiently carry passengers in a scram-jet-powered airplane-like vehicle, from the surface of the Earth, to low-Earth orbit. This development also brought to fruition a dream that went back as far as the space program itself—the ability to travel between the farthest points on Earth in a couple of hours, rather than the better part of a day.

Brazil, fortunate enough to be located at the Equator (the closer to the Equator, the less energy needed to launch into orbit), inaugurated its Alcantara launch facility in 2011, and is now a major interplanetary space port, especially servicing vehicles produced by nations in the Southern Hemisphere.

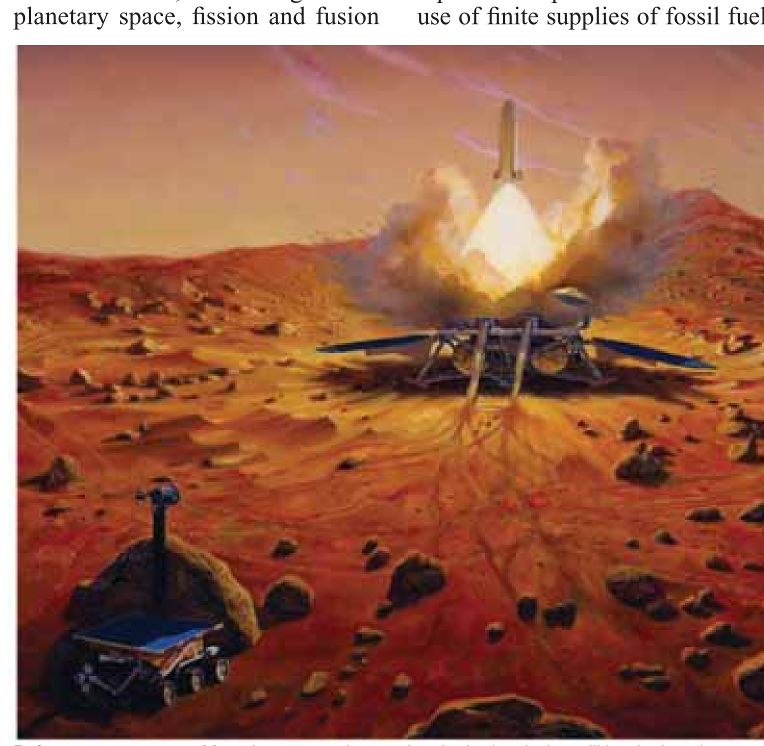
Japan and Europe took up the task, along with Russia, of building unmanned spacecraft to bring cargo to the variety of Earth-orbiting space stations, satellites, Lunar space vehicle assembly, repair and check-out garages, and other infrastructure. These nations, plus China and India, by 2017, had also deployed fleets of manned vehicles, to shuttle crew members from Earth to orbit.

While chemical-fueled vehicles still have their place—in lifting large payloads into low-Earth orbit—from there, and through interplanetary space, fission and fusion power are the baseline transport systems today.

It goes without saying that meeting the challenges of developing nuclear and fusion systems that could be flown in space, made revolutionary new energy technologies available on Earth. In 2010, when the world's dying economy started to come back to life, an immediate crisis to be faced, was the lack of adequate supplies of power. It seems beyond belief today, but then, nearly *one-third* of the Earth's people did not even have access to electricity.

Faced with the reality of this crisis, virtually overnight, the silly notions that diffuse solar energy, or that burning the Earth's food supply (i.e., "biofuels") could remedy the world's energy crisis, were pushed aside. Energy flux density, the amount of power that flows past a given surface in a fixed amount of time—which the American economist LaRouche had developed as the measure of efficient power back in the 1970s—was the only criterion applied to choosing power sources.

Since the 2020s, energy has not been a constraint on Earth. Abundant nuclear power transformed not only the standard of living of all Earth's inhabitants, it created new supplies of the fresh water that nourishes life itself, an array of new medical applications, energy to power the all-electric transportation systems that have replaced the primitive and wasteful use of finite supplies of fossil fuels,



Before men are sent to Mars, in 2024, an international robotic mission will be deployed to return samples of rock and soil to be intensively examined in laboratories on Earth. In this artist's representation, an ascent vehicle is taking off from the Martian surface, to deliver its previous cargo. The rover, which collected the samples and delivered them to the vehicle, takes shelter behind a rock. JPL/NASA and enabled the industrial development of the Moon.

Krafft Ehricke's Plans Revived

None of what has been accomplished on Mars over these past 50 years, would have been possible if not for the pioneers who took on the challenge of living on the Moon. For all of the discussion and disagreements 50 years ago, as to whether it were necessary to live on the Moon before going to Mars, no one today questions the wisdom of the decision to take that route.

In fact, the conditions on the Moon are more severe, and un-Earth-like, than on Mars. By tackling the Moon first, later, when it became possible to safely go to Mars, the technologies that were needed to live there, had already been largely developed and tested—some had failed and been improved—and were proven. The Lunar test-bed did not just make Mars colonization easier; it made it possible.

At the start of the global Mars colonization program, in 2010, no one had ever lived on the Moon for more than a few days, and even that had been 40 years earlier, during the Apollo Program. Those first Lunar explorers had carried with them everything they needed. They were limited by that era's rocket technology to exploring only the near-equatorial regions of the Moon, and the near side of the Moon, which always faces the Earth. To live on the Moon for months, if not years, required an entirely new approach.

For guidance, and in order to avoid wasting any more time than had already been frittered way, the exquisitely detailed lunar industrialization plans of the visionary Krafft Ehricke were picked from the bookshelves and dusted off.

Highly energy-dense nuclear technologies, Ehricke explained, would hold the key to living in a place without an atmosphere, virtually without water, with a two-week night, with intense radiation, and wide temperature extremes. On Earth, a productive standard of living in 2010 required a per capita consumption of tens of kilowatts of electrical energy. On the Moon, megawatts per capita were required. For Mars, considering also the transport requirements, electricity consumption today is approaching the terawatt (1 trillion watts) range.

In the early 2020s, multi-megawatt nuclear fission reactors were robotically placed on the surface to provide the power for the first tens of arriving Lunar settlers. A decade later, multi-gigawatt nuclear power stations gave life to the beginnings of a Lunar city.

As the first Lunar settlement grew, industrial manufacturing followed. Underground caverns, charged with nuclear, and later, fusion explosives, separated and concentrated Lunar raw materials. Manufacturing plants outfitted with laser, electron-beam, and other directed-energy power sources shaped the structural materials into usable form. Construction sites were established to build the grand city of Selenopolis.

As Lunar industrial processing expanded, less and less semi-and finished product needed to be imported from Earth. In fact, by 2037, the flow of commerce had reversed direction.

Before Selenopolis could reach its full economic potential, fusion power was required. And the Moon itself would be key. The most efficient fuel for fusion energy—on Earth, the Moon, Mars, or in rockets—is the fusing of the deuterium isotope of hydrogen, and the helium-3 isotope. On Earth, little helium-3 remains, from deposits by the solar wind. But on the airless, weatherless Moon, there is a treasure trove of this rare and precious material, on and near the surface.

Intensive orbital studies of Lunar minerals over the 2010s, indicated regions of *relatively* higher helium-3 concentration. Immediately, the two nations of the world with the most extensive experience in mining in extremely cold climates—Canada and Russia—began a joint R&D program to develop the tools that would be effective in mining helium-3 on the Moon.

As progress on developing Dr. Chang-Diaz's plasma rocket for Mars continued, nuclear-powered freighters began making deliveries of Lunar helium-3 to fuel the fusion reactors on Earth. Later, that fuel would be needed for the fusion rockets. In fact, it turned out that the Moon, with its near total vacuum, was an ideal place for plasma-rocket engine testing, since the environment was a good analogue for what ships would encounter in interplanetary space. Happily, Dr. Chang-Diaz was still nimble enough, at the age of 79, to make the Lunar excursion in 2029, and supervise these decisive tests.

The crowning accomplishment of the Lunar program, was the establishment of Selenopolis. This first extraterrestrial home for mankind was actually not all that strange and unfamiliar to the immigrants from Earth. The city was divided into different regions, mirroring the variety of climates on Earth, with urban, rural, agricultural, industrial, and resort areas. There are museums, Gauss University, and the Jules Verne Theater, where in stunning clarity, Selenarians gather to watch the unfolding of human civilization on Mars.

On the Moon, mankind learned how to "live off the land," processing Lunar soil to extract oxygen, minerals, and materials, capturing water ice at the poles, and developing new resources that became the fulfilment of Krafft Ehricke's "Extraterrestrial Imperative."

Mankind had established a multi-planet home. His world had become "three dimensional." Here, the work of three generations had created the future, for so many more.

Above Winter in Selenopolis: While some residents of the city on the Moon enjoy ice skating and other Winter sports, others visit the Hall of Astronauts Museum, on the left. The city replicates various climates and seasons on Earth, making the Selenarians feel right at home. Courtesy of Krafft Ehricke **Right** On June 26, 2001, the Hubble Space Telescope took this stunning photograph of Mars. The most Earthlike planet, Mars has carbon and water ice at the poles, water and carbon dioxide frozen in the soil, and indications it is still an active planet. NASA/Hubble Heritage Team

The Next 50 Years

Where do we go from here? Over the next 50 years, the focus of activity on Mars will change. Now that Keplerropolis is operational, and the construction phase is drawing to a close, it is the investigation of life which will become the major focus of scientific inquiry.

For centuries, scientists speculated about whether there ever was, or if there is, even today, life on Mars. Throughout the 2010s, increasingly more sophisticated robotic explorers were sent to try to find out. The results were all ambiguous.

Finally, the most challenging unmanned mission—an international sample return—was launched in 2024, and a few precious pounds of Martian soil and rocks came back to laboratories on Earth. Still, no definitive answer.

With great agility, and the creativity that only man could bring to the task, finally, three years after the first Mars landing, scientists in the field made the stunning discovery of fossil remains of microorganisms that, at one time, lived on Mars.

The operative question now under intensive investigation, is whether there are niches that have somehow been protected from the cold, dry environment of today's Mars, where life may still exist.

Scientists have taken their cue from the extensive research on Earth, of life in extreme environments. They were shocked to find, in the last decade of the 20th Century, that life is, indeed, found in extreme temperatures, in high-radiation environments, and even in places where there is no light. On Mars, this work is being carried out with the necessary extreme care.

If scientists do find living organisms, one major question to examine, is whether that life originally came from Earth; or, whether life on Earth had migrated through interplanetary space, and originally came from Mars; or if life developed independently, on both planets. Today there are passionate adherents to each theory.

Whether or not it is found that life still exists on Mars, to make this planet truly a home for mankind, a process has been started that will create a "second Earth." Terraforming the Red Planet, as far as can be seen today, will be the work of centuries.

One is reminded of a story in the history books, that when Charles de Gaulle told a junior officer of a particular kind of tree he wanted to be planted outside his office, the officer objected, stating: "But General, that is a very slow-growing tree. It will take decades before it produces any shade." The General replied, "Then you had best get started right away!" Those living on Mars today will not be there to see it turned into a garden, but their great-great-great-grandchildren will be.

In the late 1920s, Hermann Oberth, the father of space flight, said that the purpose of space exploration was to "make all worlds habitable." That is the goal of the Second Earth project—to create a biosphere on Mars.

Over the years, scientists have put forward numerous approaches to terraforming Mars. But because this is an experiment that cannot, in any satisfactory way, be carried out anywhere else, but on Mars itself, it was decided that a number of approaches would be tried at the same time.

The first order of business, is to raise the temperature on the Red Planet, to liberate frozen water-ice, at the poles and in the permafrost, and gasify the frozen carbon dioxide, to thicken the atmosphere. This will begin a self-reinforcing "runaway" greenhouse effect (once so foolishly feared on Earth).

One of the pathfinder technologies, used in Lunar orbit over the past 20 years, is a set of reflective mirrors. These Solettas, or artificial suns, designed by Ehricke in the 1970s, from an original idea of Oberth, are directing light reflected from the Sun to illuminate perpetually shadowed, water-ice-rich polar regions of the Moon.

On Mars, engineers have determined that the first step, now underway, needed to transfer this technology, is the deployment of a modest-sized orbiting mirror, able to raise the temperature in a given area, by a few degrees. Eventually, once Solettas reach the terawatt level of power, this warming would activate the hydrosphere on Mars, liberating some of the frozen water. The size of the mirror, at a radius of 125 kilometers, required that it be manufactured entirely out of Martian material.

A second experimental approach now underway, is the "seeding" of the Martian atmosphere with halocarbons. These greenhouse gases will slowly raise the global atmospheric temperature and pressure on Mars, one day liberating explorers from the bulky spacesuits now donned for field work, requiring only scuba-type breathing gear. Once genetically-engineered plants can start living in the carbon-rich atmosphere, they will oxygenate the air, eventually making Mars habitable, without the need for special equipment.

We now know there was life on Mars before man arrived. How many other bodies in our Solar System were, or still are, abodes of life? This will be intensively studied, to the far reaches of the outer plants, over the next 50 years.

And starting today, the Kepler II spacecraft is on its way beyond our neighborhood of planets, to search for life on planets orbiting other stars.

Throughout human history there have always been naysayers and pessimists. The establishment of the city on Mars is just the most recent proof, that the human spirit can overcome any crisis: that by marshalling his unique creative abilities, man discovers the laws of the universe, and then shapes the universe to the betterment of all mankind.

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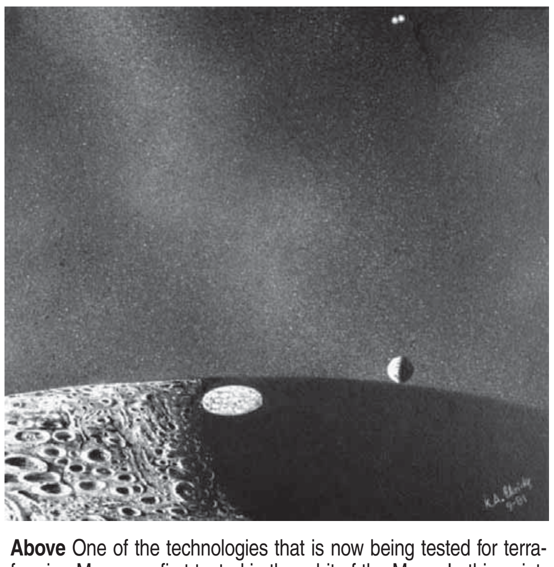

Above One of the technologies that is now being tested for terraforming Mars was first tested in the orbit of the Moon. In this painting, each one of Krafft Ehricke's Lunettas is providing the equivalent to a full Moon, lighting the perpetually dark lunar pole. Larger orbiting mirrors can be used to raise the temperature of Mars. Courtesy of Krafft Ehricke **Right** The mission of Kepler I, launched in 2009, is to identify Earth-sized planets around other stars. This image shows the region of the Milky Way where the Kepler spacecraft is pointed. Each rectangle indicates a specific region of the sky covered by each Charged Couple Device element of the photometer. Carter Roberts, Eastbay Astronomical Society/NASA