# Planet Moon Philosophy

**By David G. Schrunk**

Humankind is now poised to undertake the largest and most promising venture in history: the global exploration, development, and human settlement of the Moon. The transformation of the Moon into an inhabited sister planet of the Earth (the “Planet Moon Project”) will establish a link between our ever-growing scientific expertise and the unlimited resources of space.[1] When that link is secured, the following will be realized: (1) the Earth will be supplied with an abundance – an over-abundance – of energy and material resources, thus dramatically improving the living standards and quality of life for all people, (2) large scale operations (e.g., planetary engineering projects) will be conducted in space, (3) every region of the solar system will be explored in depth, and (4) the first missions to the stars will be initiated.

The Moon is the logical site for the next stage of large-scale space exploration and development. We now have the ability and cultural maturity to transform the Moon, in a peaceful and responsible manner, into an inhabited sister planet of the Earth and thus reap the benefits of becoming a multi-world species and eventual masters of the solar system. All that remains is to define goals, set timetables, and apply our technological, financial, and cultural expertise to the accomplishment of this significant next step in the emergence of humankind as a true spacefaring civilization.

## Lunar Resources

Over the past several decades, both manned and unmanned scientific missions have yielded information on the structure and resources of the Moon. The lunar regolith has been found to contain an abundance of elements, such as iron, silicon, titanium, aluminum, and oxygen, and concentrations of water and organic compounds have been discovered in the north and south polar regions. In addition to these resources, the Moon receives a reliable, unlimited, and unobstructed source of energy in the form of sunlight. Thus the Moon has virtually all of the materials and energy needed to support large-scale industrial operations and human settlements and the next critical phase of lunar development, in-situ resource utilization (ISRU), is ready to begin.

## First Lunar Base

Within this second decade of the 21st century, several nations and commercial enterprises will deliver tele-operated and semi-autonomous robotic devices to the surface of the Moon. These robots, which will include solar cell and additive (3-D) manufacturing devices, will be the first elements of an unmanned industrial base that excavates, transports, and processes indigenous lunar regolith materials into useful products, such as solar cells, building materials, replacement tools, and other needed items on the Moon.

The site for the first unmanned base will likely be on the Earth-facing side of the south polar region of the Moon. There are several promising sites in the south polar region, such as the summit of Mons Malapert,[1] that always have the Earth in view for continuous telecommunications and that receive over 300 days of sunlight per year for the generation of solar electric power. A base in the south polar region will have access to increased concentrations of water and organic compounds that will be useful for industrial operations and eventual human habitation. The tall peaks and deep depressions of this region also offer the opportunity for the placement of long line-of-sight telecommunication links and power beaming facilities.

After a “critical mass” of manufacturing equipment (ovens, crucibles, drills, lathes, 3-D fabricators, etc.) has been transported to the first base, lunar regolith resources will be used as feedstock for the production of virtually all of the products that are necessary for the construction of infrastructure elements and human habitats.[1, 2] For example, lunar iron and aluminum will be used to create pipes, panels, wires, wheels, and structural beams, and lunar silicon will be used for the production of photovoltaic (solar) cells, transistors, fiber-optic cables, mirrors, and lenses. Oxygen and other light elements that are not needed for unmanned activities will be recovered from lunar mining and manufacturing operations and stored for later agricultural and human habitation applications. While the relative abundance of elements on the Moon is not ideal, sufficient quantities are present to build a substantial infrastructure that will support scientific exploration and permanent human settlements.

Of significance, the growth of the unmanned lunar base will be <u>exponential</u>. For example, robotic devices will be used for the construction of solar panels. As more solar panels are added to the lunar electric grid, the increase in electrical power will be used by additive (3-D) manufacturing devices to make more solar-panel manufacturing machines that then make more solar panels, etc. Since abundant, reliable electrical power is the key to large-scale development, priority will initially be given to the fabrication of solar cells from lunar materials. The generation of electric power on the Moon from the first lunar-made solar photovoltaic cell will be a milestone in space exploration because it will prove unequivocally that human enterprises can be self-supporting in space.

**Circumferential Infrastructure Networks**

In one likely scenario the first elements of the lunar electric power grid will be delivered from Earth to the summit of Mons Malapert and configured into an electric power grid.

The grid will then be extended, by the creation of more solar panels from lunar regolith materials, in east and west directions from the lunar base to create a circumferential electric grid around the Moon at 85° south latitude.[1] The advantage of a circumferential solar-powered electric grid is that 50% of the solar panels will always be in sunlight, thus delivering continuous electric power to the grid, and new equipment that is delivered to the Moon from the Earth can simply be plugged into the fully functioning electric power system.

The construction of the lunar electric power system will give rise to the need for an efficient surface transportation system that can deliver raw materials, tools, building materials, and, eventually, people between manufacturing facilities and construction sites. To meet these needs, a railroad system will be created. The "lunar railroad" will be an effective, efficient, and simple (mostly automated) logistic system on the Moon and it will avoid most of the problems of lunar dust accumulation that plague off-road vehicles. Rails for the railroad can be made from lunar iron, for example, and used to create a simple two-track rail line from the first base to other areas in the south polar region, including the geographic south pole. A "southern rail line" will greatly increase the ability to carry out exploratory missions and will facilitate the growth of all lunar projects.

The challenge of building the circumferential rail system (beginning with tele-operated robotic devices) will be similar to the challenge of building the solar-powered electric grid and both construction projects can thus be undertaken simultaneously. Since communication systems and pipelines for the transport of fluids and for thermal management will be needed on the Moon, these infrastructure elements will also be constructed in parallel with the railroad and electric power networks. Eventually the rail line and other utilities will be extended northward to the mare/equatorial regions and then to the north pole, thus creating an infrastructure network that encompasses the global structure of the Moon. The circumferential utilities network of the south polar region is depicted in Figure 1.

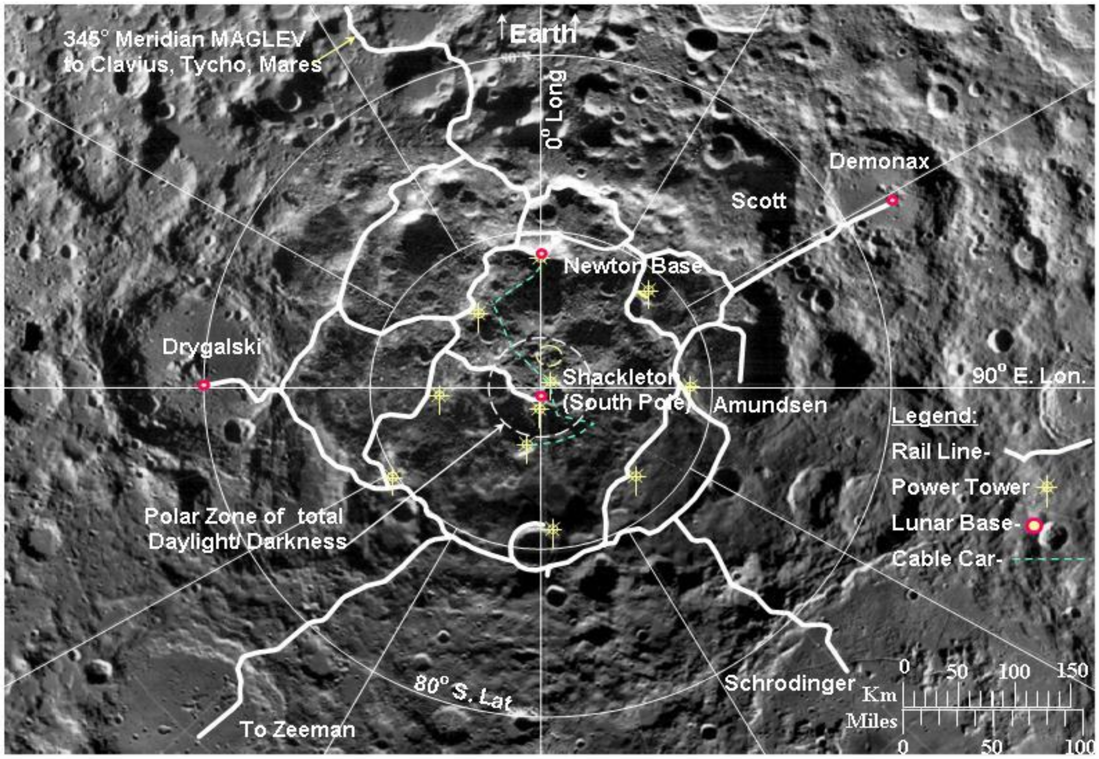


**Figure 1. Circumferential Utilities Network at the Lunar South Pole**. The initial lunar railroad, solar power, communication, and pipeline networks will be placed around the circumference of the Moon at the South Pole. These networks will then be extended to form a global lunar utilities network (Illustration from Schrunk et al.[1]).

Power levels in the circumferential grid will increase to the multi-megawatt range as construction of the utility infrastructure continues and experiments will be conducted with the first microwave beaming of electric power from the Moon to the Earth. With continued growth, it will become possible to supply the Earth with terawatt levels (one terawatt = one trillion watts) of clean, reliable, low-cost solar electric power. Lunar development will thus contribute to increased living standards on Earth and to the "greening" of Earth's biosphere through the decreased need for and usage of fossil and fission fuels and by the use of excess power to clean up toxic wastes and increase supplies of potable water by desalinating ocean water, etc.

**Return of Humans to the Moon**

Within a decade after the first unmanned base has been established, humans will return to the Moon on short-duration missions (60-90 days) to service and maintain complex machinery and to supervise operations. Work will also commence with the development of reusable rocket systems and with orbiting stations in "figure 8" Earth-Moon orbits that ferry people between the Earth and the Moon.[1] When a reliable lunar electric power system is in place and pressurized underground habitats (for protection from radiation, temperature extremes, micrometeorites, and lunar dust) have been constructed, regenerative life support systems and agricultural modules will be delivered to the lunar base. Humans will then return to the Moon for longer periods and all aspects of lunar industrial and settlement activities will be expanded.

By the middle of the 21st century, thousands of people will be able to live permanently in each of several large underground malls that have Earth-like living conditions, including luxuriant vegetation and large lakes of water (Figure 2). Given the growing range of lunar activities, including tourism, a broad cross section of humanity will participate in creative and economic pursuits on the Moon. Sculptors, artisans, athletes, and musicians will join entrepreneurs, technicians, and scientists in the unique conditions of "Planet Moon" to create a rich, diverse, and desirable cultural environment for people to work, live, and even retire. The Moon can become a human laboratory for meeting the challenges and hazards of off-world existence. This knowledge, learning, and experience can then be transferred to the exploration and settlement of other sites in the solar system, such as Mars.

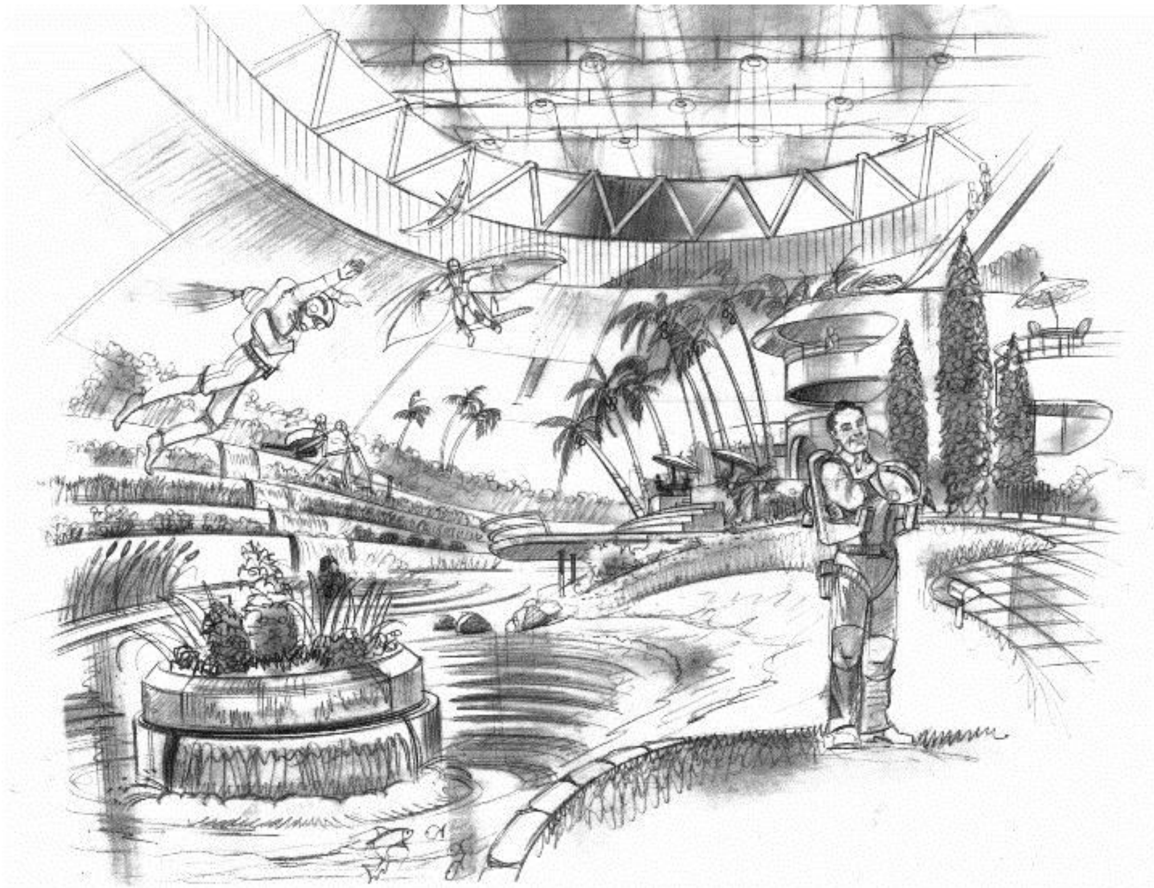

**Figure 2. Underground Mall on the Moon**. Underground malls on the Moon will support large populations in Earth-like conditions (Illustration from Schrunk et al.[1]).

When humans permanently inhabit the Moon, within the next two to four decades, they will explore mountain ranges, mares, craters, and rilles, as well as lava tubes that have been sealed for billions of years. By then the Moon will be our principal platform for making astronomical observations. Thousands of lunar-made telescopes will be placed at regular intervals around the Moon in a coordinated network so that objects of interest in the universe, including the Earth and the Sun, may be observed continuously at all wavelengths of the electromagnetic spectrum under ideal viewing conditions.

## Planet Moon

With proper planning and execution, the “Planet Moon Project” will reflect our highest aspirations and provide significant benefits for the people of the Earth. It will involve international cooperation and draw upon the expertise of governments, entrepreneurs, investor-based commercial enterprises, and non-profit institutions, such as universities and foundations. It will provide large scale, high-value employment for the people of every nation and will contribute to advances in all scientific disciplines. As experience with lunar operations increases, the scientific and industrial capability of the Moon will approach parity with the Earth, perhaps within three to five decades after the founding of the first unmanned base.[2]

A wide range of research projects will use the unique conditions of the Moon to advance knowledge in such areas as materials science, power beaming, superconductivity, and bioscience. Advances in existing technologies will accelerate the phased development of the Moon and it may be expected that new, as-yet-unimagined innovations will greatly enhance our evolution into a spacefaring species. A magnetic levitation rail system will provide high-speed access to population centers of the Moon (Figure 3), and abundant supplies of solar electric power will be beamed from the Moon to the Earth and other locations in space by the lunar power system.[1]

**Space Exploration**

The evolution of the Moon into a permanently inhabited planet will lead to a fundamental change in the roles of the Earth and the Moon in the exploration and utilization of space. It is natural for present-day Earth-bound peoples to regard space missions only in terms of Earth-based programs (e.g., the construction and launch of robotic missions to Mars). But as humans establish a permanent human/industrial presence on the Moon, Earth-centered thinking will give way to the realization that the Moon will be humankind's principal base for the exploration of space.

**Figure 3. Mag-Lev Train**. A magnetic levitation rail system will provide high speed transportation on the Moon (Illustration from Schrunk et al.[1])

Thousands of spacecraft will be manufactured on the Moon and launched by electromagnetic “mass drivers” to all points of interest in the solar system and, eventually, to nearby star systems. Mass drivers on the lunar surface will also operate “in reverse” to recover spacecraft, including manned spacecraft, from lunar orbit. The Moon will thus become a “spacecraft carrier,” analogous to an aircraft carrier, that uses mass drivers to launch and recover spacecraft to and from cis-lunar space (Figure 4). Communication, power, transportation, and life-support systems that have been manufactured on the Moon will be launched, by mass drivers to Mars and other locations in space in support of the exploration and human settlement of the solar system. Solar power satellites will be manufactured on the Moon and launched into orbits around Earth and Mars to supply those planetary bodies with an abundance of beamed electric power.

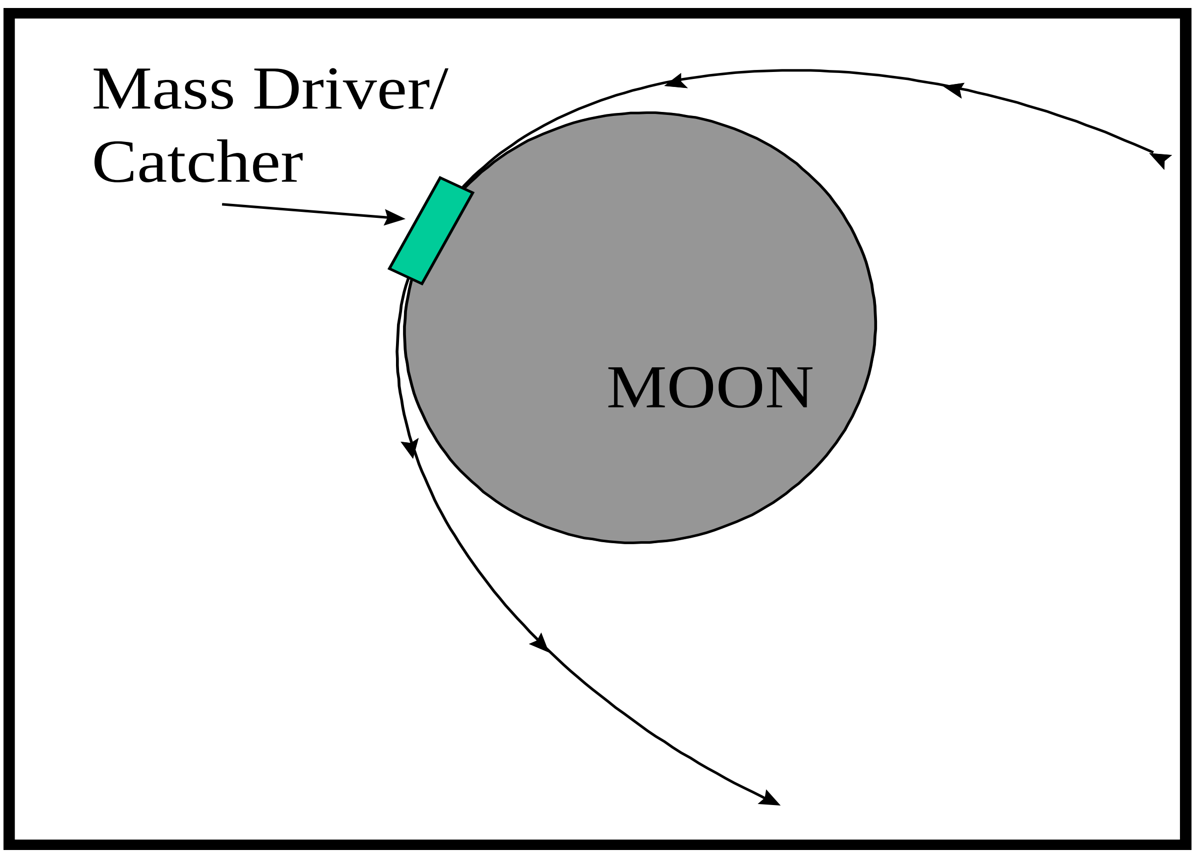


**Figure 4. Mass Driver on the Moon**. Electromagnetic mass drivers will launch and recover spacecraft to and from cis-lunar space thus eliminating the need for rockets on the Moon (Illustration from Schrunk et al.[1])

Also, solar sails, made from lunar aluminum (Figure 5) will likely become a predominant form of solar system transportation in space later in the 21st century.[1] Solar sails are highly efficient, because the source of their energy is sunlight; the sails only need to be positioned in proper alignment with the sun to produce the thrust that propels them from one part of the solar system to another. The pressure of sunlight on a sail decreases in proportion to the distance of the sail from the sun and for this reason solar sails have much greater performance in the inner solar system (Mercury - Venus - Earth - Mars) than in the outer solar system. Another advantage of solar sails is that laser beams can be used to augment their propulsion. A laser located on the Moon could be used to add propulsive forces to a solar sailing ship and thus decrease the transit time for high-priority missions such as the transportation of astronauts from the Earth-Moon system to Mars.

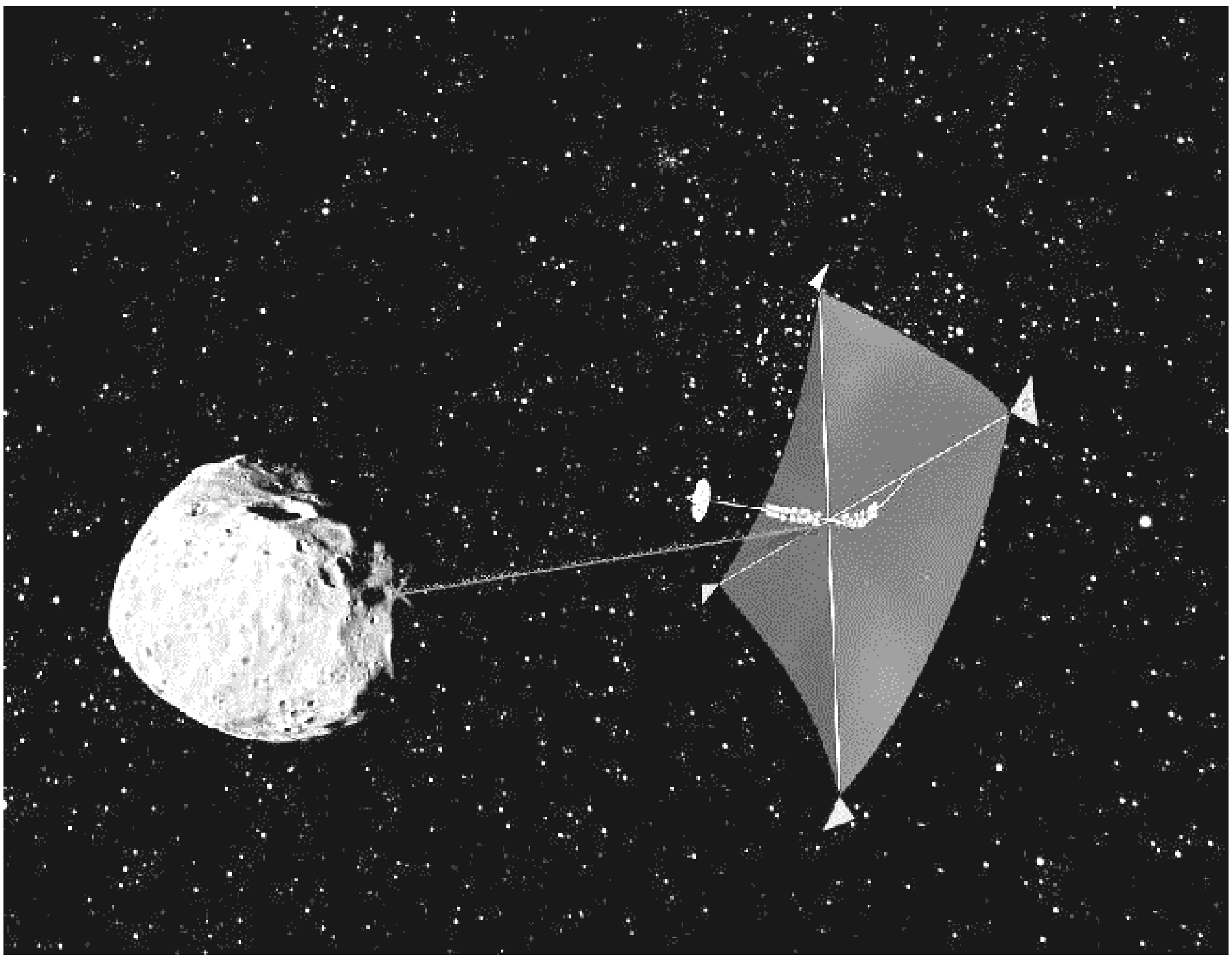

**Figure 5. Solar Sail Transport of Asteroid**. Fleets of solar sails made from lunar aluminum will ply the reaches of the solar system on cargo and research missions (Illustration from Schrunk et al.[1])

Asteroids and "burned out" comets in Earth's orbital vicinity, especially those that pose a threat of collision with the Earth or the Moon, will be moved out of harm's way (e.g., by solar sails) and mined for their hydrocarbons, water, metals, and other constituents. These resources will then be delivered to the Earth, Moon, and cis-lunar locations as needed. Eventually the lunar-based manufacturing system will gain access to resources throughout the solar system.[1, 2]

**Optimistic Forecast**

The transformation of the Moon into an inhabited and fully autonomous sister planet of the Earth before the end of this century might seem to be an overly optimistic goal. However it is well within our reach, for several reasons. First, virtually all of the aforementioned technologies already exist – it is just a matter of going to the Moon and applying the knowledge and technology that already exists. Second, the "nominal" rate of growth of scientific knowledge and technology is exponential, and ongoing, spectacular scientific/technological advances can be expected in fields such as computers, robotics, and nanotechnology.[3] Third, raw materials for the manufacturing base of the Moon will come from the solar system, whose resource base is many orders of magnitude greater than those of the Earth. Metzger et al.[2] estimate that the placement of a 41-metric-ton lunar industrial base on the Moon will grow, exponentially, over a period of a "few decades," to reach an industrial capacity that is millions of times greater than that of the Earth – and will draw on solar system resources that are billions of times greater than those of the Earth.

**Endless Frontiers**

The desire to explore and settle new lands is a defining characteristic of the human species; to remain in a state of ignorance of any aspect of the physical universe, when the means to end that ignorance are available, is completely contrary to human nature. It is inevitable, therefore, that, in the coming decades, we will undertake the global exploration and settlement of the Moon and become a multi-world species. The present, limited "closed Earth" mindset related to overpopulation, intransigent poverty, and the depletion of Earth's resources will then give way to a much grander "open space" vision of broad-scale advances for all humankind based upon access to the unlimited resources of space and the opening of endless frontiers.

**Notes**

[1] D. Schrunk, B. Cooper, B. Sharpe, and M. Thangavelu, *The Moon: Resources, Future Development, and Colonization*, 2nd ed. (New York: Wiley-Praxis, 2007).

[2] P. Metzger, A. Muscatello, R. Mueller, and J. Mantovani, "Affordable, Rapid Bootstrapping of Space Industry and Solar System Civilization," *Journal of Aerospace Engineering*, April 2, 2012 (doi: 10.1061/(ASCE)AS.1943-5525.0000236).

[3] Ray Kurzweil, *The Singularity is Near: When Humans Transcend Biology* (New York: Penguin, 2005).



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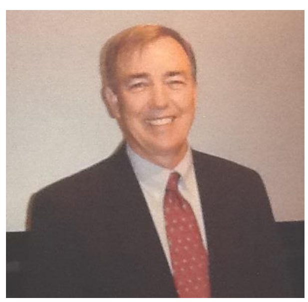
**About the Author:** David G. Schrunk is an aerospace engineer and medical doctor with board certifications in the medical specialties of nuclear medicine and diagnostic radiology. Dr. Schrunk retired from the practice of medicine and now dedicates his time to his two passions: the future exploration and human development of the Moon and the science of laws. He has authored many scientific papers on lunar development issues and is a co-author of the book, *The Moon: Resources, Future Development, and Colonization*, published by Wiley-Praxis in 1999. The second edition of the "*Moonbook*" was released by Springer-Praxis in 2007. Dr. Schrunk founded the Quality of Laws Institute in 1995 and authored the book, *THE END OF CHAOS: Quality Laws and the Ascendancy of Democracy*, published in 2005 by the Quality of Laws Press. Dr. Schrunk lives in Poway, California with his wife, Sijia, son, Erik, and daughter, Brigitte.



**Editor's Notes**: Dr. David Schrunk is the only medical doctor, aerospace engineer, Space scientist and author, and Founder of Quality Laws Institute in the world. And he is a Kepler Space Institute Faculty Member and Member of the Board of Editors for this Journal of Space Philosophy. It has been a special privilege to share Kepler Space events and work with him. He is a remarkable intellectual and innovative thinker. I first met Dr. Schrunk when invited to lunch with three of his Lunar Industry and research professionals at Torrey Pines, California on 15 December 2009. His capabilities and achievements have been educating me ever since. I videoed Dr. Schrunk, author Dr Phillip Harris (see his *"Humanity's Destiny is Offworld*" article in this Issue #1), Dr. Thomas Matula, and Transorbital Corporation President, Dennis Laurie, at that luncheon. You can see and hear them each making a short statement about the critical importance of the Moon to the future of human Space exploration, development and settlement at www.bobkrone.com/node/222.

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