Going Beyond The Status Quo In Space

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Sunday, June 28, 2009

"Perhaps worst of all, we ~~were~~ (are) hearing an incessant drumbeat that the world was running out of room and resources, that we faced a world of limits, a zero-sum game in which our children would have to settle for less in life than we had. Many young people who picked up that message-that success would be elusive--concluded that study and hard work might not be the kind of blue-chip investments they were a generation earlier. The space program itself was viewed by many as a too-expensive series of stunts that would be unaffordable in the bad times ahead. It was certainly not seen in terms of an investment in breaking out of those limits and into new and better times."

Setting The Context

The preceding paragraph was not written in the last few years. It is an excerpt of a speech given by Dr. George Keyworth, Director of the Office of Science & Technology Policy (OSTP) almost 25 years ago. Therein lies the issue before us today when considering how to re-craft the "Vision for Space Exploration" into a policy that can garner the continuing support of the Congress and the American people. Our exploration effort beyond Low Earth Orbit (LEO) must make a concrete connection to addressing the critical issues that confront our nation and our civilization today. This is the subject of this missive.

Declaration

The next step in our space program is the development of a true space faring civilization using the Moon as a stepping stone. Elements of such a system include a lunar spaceport, settlement, and industrial infrastructure to support the further economic development of the Solar System. Pursuing this goal requires a different way of thinking about space infrastructure and operations. Reducing operating cost is paramount. We must accept high-payoff new technologies and manage their risks until they are mature. But the payoff is huge: a new economic frontier in space.

Why the Moon?

While appearing barren, the Moon has the resources upon which to build a prototype space civilization. It is a power-rich environment, permitting initial steps to be undertaken using proven, inexpensive solar power generation technology. The Moon is readily accessible from Earth at almost any time. This accessibility makes it a practical site for such a pioneering development - one that is convenient enough to Earth so as to enable trade, travel and telepresence operation. In contrast, Mars and the inner solar system asteroids have infrequent travel opportunities and comparatively long trip times. They won't work for first steps towards economic development of the solar system. With experience and technology from developing the Moon in hand, Mars can then be settled and the rest of the inner solar system can be developed in a cost effective manner.

What Are Our Concerns Today and How Does a Lunar Spaceport Address Them?

Our major concerns today are energy, resources, sustainability of our civilization, and environmental quality. Interestingly, a lunar spaceport could address, in microcosm, all of the challenges and concerns that face our civilization here on the Earth in macrocosm. If we were to design a civilization today on another planet, which is essentially what the lunar spaceport would be, what are the most important needs that must be addressed?

Where on the Moon?

On the Earth, real estate value is based upon desirability and demand. For primitive societies (which the new spaceport will be in the context of extraterrestrial civilization), all cities were located near water with fertile land and other resources. This will be true on the Moon as well.

Because of the cycle of two weeks of daylight followed by two weeks of night in non-polar locations, electrical power systems must be dramatically over-specified for solar-based systems. Otherwise, we must rely on nuclear power to develop a productive spaceport. In order to minimize costs (which was also foremost in our ancestor's minds), we must begin at one of the near-permanently sunlit polar locations - either north or south. If we do not use polar locations, solar power and overall energy supplies will be extremely limited, which limits the growth potential of the spaceport.

Nuclear power requires additional billions in development costs and no matter how desirable large energy supplies from nuclear are, funding limitations eliminate this in the near term. Additionally, nuclear power is not a sustainable option for lunar electric power even in the mid term as the reactors and fuels must come from Earth until a very mature infrastructure is present on the Moon where fuel can be reprocessed and reactors constructed.

Lunar polar terrain also has the advantage of being a relatively benign thermal environment, with typical surface temperatures of about -50º ± 10º C, as opposed to the enormous temperature variations (-150º to 100º C) of non-polar sites. Lunar polar locations also trump locations anywhere on Mars at this time. With a lunar day of 708 hours, a polar location gives around 567 hours of Earth standard (1365 W /m2) solar energy. At some polar locations, illumination time approaches 100%, which gives further leverage. Using this resource dramatically lowers costs as every hour gained lowers energy storage requirements and further enables growth. On Mars, only about 770 W /m2 is available. With large seasonal swings and an atmosphere that is often obscured by massive dust storms, solar power is unusable for any meaningful spaceport settlement, thus driving up costs.

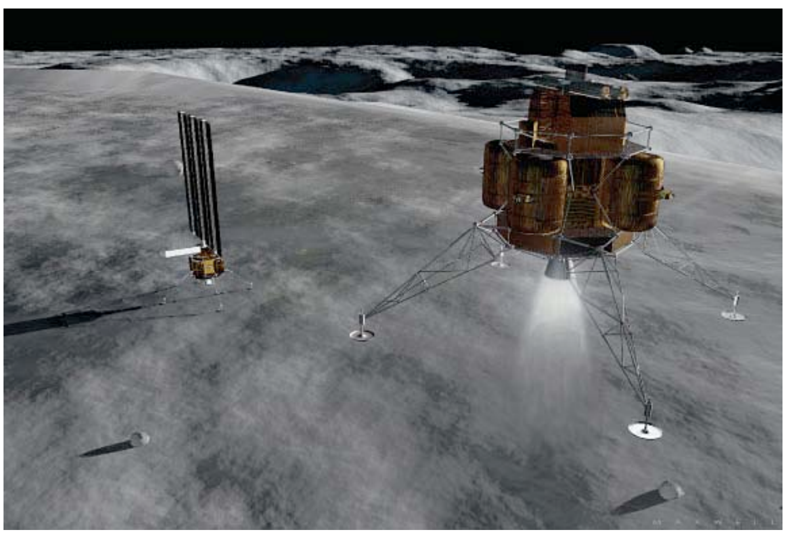
One additional factor: mission opportunities to Mars occur once every two years Vs once every two weeks for the Moon. These factors alone would add tens of billions of dollars in cost to any substantial settlement, and all of these costs are upfront.

Energy

Without access to abundant energy, it is not possible to support a spaceport that is not dependent upon terrestrial resupply on the Moon or anywhere else. To go more beyond mere subsistence we need substantial amounts of energy. In looking at the different processes and desires for In Situ Resource Utilization (ISRU), we recommend that a commitment be made to supply the spaceport with 1 megawatt of solar power.

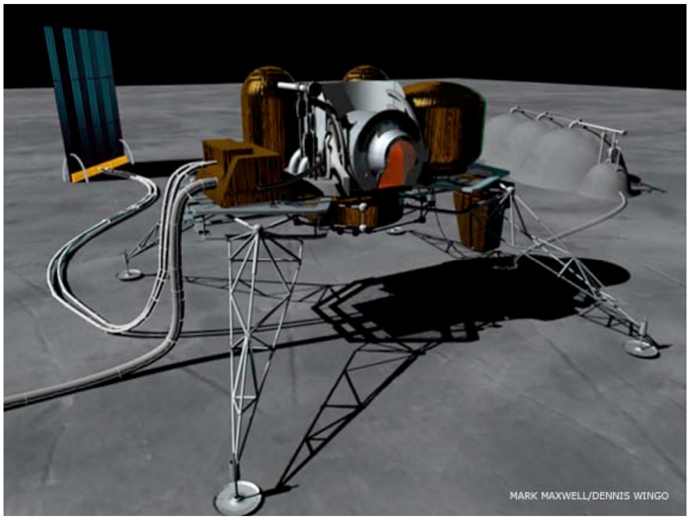
Energy is the primary means toward bootstrapping the lunar spaceport beyond a total reliance on supplies shipped from Earth. In the fertile crescent of the Middle East 8,000 years ago, energy in the form of draft animals served as the spark for agricultural production. This increase in productivity allowed for the specialization of labor that led to the world's first cities.

Placing solar power at the lunar spaceport does not require a heavy lift launch vehicle. Indeed, it is entirely reasonable to use any of the existing stable of launch vehicles to do this. The benefits are obvious: you could use U.S. commercial suppliers and or have international partners provide launch services as part of the lunar spaceport. With approximately the same throw weight, the Ariane V ECA, the EELV Heavy, or Proton could place around 250 kilowatts of power on the lunar surface with a single launch. A conceptual design for this is shown here:



Power Lander Approaching Touchdown With Previous Lander Deployed. (image by Mark Maxwell, copyright Dennis Wingo)

There are many benefits from having this high level of energy available. To begin with, 1 megawatt is enough to begin serious ISRU production, no matter what process is used. Vacuum induction furnaces or microwave energy could be used to melt regolith to 2,000º C. The unmelted slag can be scraped off and stored for future processing. One megawatt is enough to provide light and power for dozens of people on the surface. Also, the lessons learned in designing high efficiency solar power and power management systems can be fed into the terrestrial economy for solar power installations.
A conceptual vacuum induction furnace is shown here:



(image by Mark Maxwell, copyright Dennis Wingo)

With a megawatt of power, we can experiment with several different types of ISRU processes. What processes are used will be dictated by what the local resources are.

ISRU-ISFP

For a primitive extraterrestrial spaceport/settlement, resources will be at a premium. From studies of lunar regolith samples returned during Apollo it is well known that between .1-1% of all lunar regolith is composed of meteoric nickel iron. Additionally, vapor-deposited reduced iron comprises another few percent of any agglutinate rocks. Using the simplest possible ISRU vacuum induction furnace, tons per week of metal can be obtained, as well as several tens of kilograms of water and other volatiles. Volatile concentrations are enhanced even in the non-permanently dark areas in the polar regions. This is enough metal to begin building structures using simple regolith molds that have been sintered using microwaves. The volatiles are insufficient for rocket fuel but would be useful for crew life support consumables, food growth, and as a feedstock for more advanced ISRU processes.

Using this simple ISRU process, enough metal could be processed within a couple of months to build a 10 x 10 x 4 meter structure several inches thick. When covered by the slag from the induction furnaces this would offer sufficient protection from even the most violent solar flares. Living space is more valuable than anything else on the Moon for humans. Building this initial living space would provide ample room for a crew of several people.

With living space you can then start growing food in a separate compartment for food production. Hydroponics has been proven in these applications. With the importation of just a bit of fertilizer from the Earth (brought up by a modular, standardized lander on a Soyuz, Falcon 9, H-II, or light EELV) food production for the crew on the lunar surface would be possible, dramatically cutting the demand for Earth resupply.

As time passes, facilities, capabilities and activities would be expanded. Additional living space, bulldozer chassis, large machine bodies, and other metallic hardware could be built using methods known for centuries on Earth. Using machine shops sent up from Earth to build the large heavy structures on the Moon, we transform the logistics system and eliminate the need for any further development of heavy lift launch from Earth.

Why Heavy Lift is Not the Long Term Solution

Heavy lift launch vehicles for the Moon and beyond are needed for only one reason: to launch large, ground integrated systems from Earth. If you look at the manifest of any architecture developed over the past 40 years, you will see rovers, habitats, and other large ground integrated payloads. With even the most primitive ISRU described here, the need for most of these large systems diminishes. With a slightly more sophisticated ISRU and a machine shop, there is a great deal of fabrication that can be done on the Moon that completely changes the complexion of the hardware needed from Earth.

Instead of lofting large integrated systems, only parts and information are needed from Earth. These parts would include motors, computers, actuators, seals, sealing material, etc. Heavy lift is simply not needed for delivering these things. Small parts could be carried to the Moon on any commercial ELV. In addition, the computers, actuators, and other hardware from the landers themselves can be reused on the lunar surface, providing a force multiplier in terms of the ratio of the overhead of the lander versus its payload. This can be taken even farther and the materials of the lander itself (including the landing legs, fuel tanks, and other hardware) can be tailored for reuse on the surface. A very preliminary estimate suggest that upwards of 80% of the mass of the lander could be reused on the Moon i.e. several tons of hardware when you consider the big landers that have been suggested.

As commerce with the lunar spaceport continues, the flight rate of landers from Earth will eventually increase. At some point the flight rate will be high enough to justify the development of a reusable Earth-to-orbit system to carry people and hardware to the International Space Station (ISS). Reusable space vehicles, described below, can be introduced even before reusable launchers since their development is less challenging and less costly.

Reusable Space Vehicles

For over two decades, we in the space advocacy community have run around in ever increasing circles of futility with regard to developing reusable launch vehicles. It is extremely difficult to build one that carries useful payload from the bottom of Earth's gravity well, punch through the atmosphere, make it to space, deliver payloads, and return to Earth. However, this is not the case for vehicles used exclusively in space: the ISS being the prime example of this today.

The ISS has been operational for over a decade and continues to operate with periodic resupply, refurbishment, and upgrades. We are increasing the ISS crew size to six people, all of whom want to be useful. The ISS, while not in the best orbit for lunar exploration support, is BUILT and OPERATIONAL, thus being several billion dollars less costly than any paper space station located at an inclination of 28.5 degrees.

A reusable space vehicle, based upon ISS modules (still in production for the Orbital COTS program and the European ATV) using aerobraking could easily be built at the ISS. It could then cycle between the ISS and Low Lunar Orbit (LLO) as was described in many studies, including the old Space Exploration Initiative (SEI) baseline in 1989. The old dual keel suggested in early Space Station Freedom designs is not needed for this task.

Anyone who says that this would be inordinately difficult merely needs to speak to Dr. John Grunsfeld about his team's magnificent work refurbishing and upgrading the Hubble Space Telescope or the crews who have done such a masterful job building and maintaining the ISS.

It is staggering to imagine that the current plan for Constellation would discard this hard won capability. It is our opinion that our current orbital assembly and repair capability represents an invaluable national asset that would be extremely shortsighted to throw away. The lunar lander can be designed to be reusable as soon as we can make propellant for it on the Moon. This works quite well even if we only make oxygen. With a depot in lunar orbit or at L1 and propellant supply on the lunar surface, the lunar lander could fly from Earth orbit to the Moon, land on the Moon, and come back to Earth orbit (using aerobraking).

With reusable space vehicles, reusable landers, existing launch vehicles (with some upgrades), ISS as a staging point, and ISRU on the Moon for oxygen, we can begin to refuel vehicles and cut the logistics burden by more than 50% compared with launching that oxygen from Earth. A study we conducted last year indicated that the NASA Altair lander would provide a lunar Single Stage to Orbit (SSTO) with a cargo capacity of 25 tons to LLO. With multiple reusable landers some serious propellant deliveries could be made to lunar orbital space.

Crew Selection

The crew of such a lunar outpost would be radically different from the scientist-astronauts that have comprised NASA's cadre of astronauts. We will need engineers, machinists, and "blue collar" workers to make the lunar spaceport work. Yes, we are going to need people who can clean dishes and toilets as well. In other words, this will be more than just those with the "Right Stuff" - it will take people who know how to do stuff right, in design, manufacturing, construction and maintenance. This will do more to excite our fellow citizens than any scientific discoveries we might make as it brings space exploration and development into a realm that is understandable and accessible.

Just the Beginning

These ideas are not new. People such as Mike Duke have pushed similar concepts for decades. Yet, at each crisis point, these ideas fell out of favor as it was perceived to cost too much to implement. if we If we have any serious intention of becoming a space faring civilization, it is increasingly apparent that it costs too much not to implement these ideas. So what is the value of the future described here to our fellow citizens on Earth?

A robust operational capability on the Moon will allow us to build space vehicles there that simply could never be built on Earth. These vehicles could carry heavy structures from the Moon to geosynchronous orbit to build large platforms for communications, remote sensing, climate and solar monitoring.

Just this past week, congressional hearings related to the costs for our next generation of these satellites (NPOESS) are indicating a 5-fold overrun to almost $14 billion dollars and delays of another several years. The same situation exists with regard to national defense payloads. It is quite clear that our current path is leading us toward an almost complete paralysis in this strategically critical realm. Think about the advantages we'd have if these large platforms were already in place and all that had to be built where new instruments that could be carried up - at will - to add to and expand existing systems.

With hardware and fuel provided from both Earth and the Moon, we would create an transformation in our ability to move at will throughout cislunar space. Current computers are trillions of times more powerful than the computer that guided the Apollo 12 Lunar lander to within 155 meters of its intended landing site. Does anyone want to argue that we are not up to that level of accuracy throughout cislunar space today? DARPA's Orbital Express, and several vehicles that have the ability to rendezvous and dock/berth to ISS also attest to this capability in low Earth orbit.

It is clear to us is that we are neither doing the right things in space nor are we are doing things right. Frankly, we do not think that it is possible to do much worse. The United States spends more money on space through our government than all other governments put together and we get less results on a dollar for dollar basis. Day by day more bad news about slipped schedules, enormous cost overruns, and lost capabilities make it into the news. It is beyond time to change the way that we conduct space flight, and if we choose to make this spaceport/settlement a reality, we will completely transform our aerospace industrial system. This rearrangement will save taxpayers billions of dollars while increasing our operational capabilities.

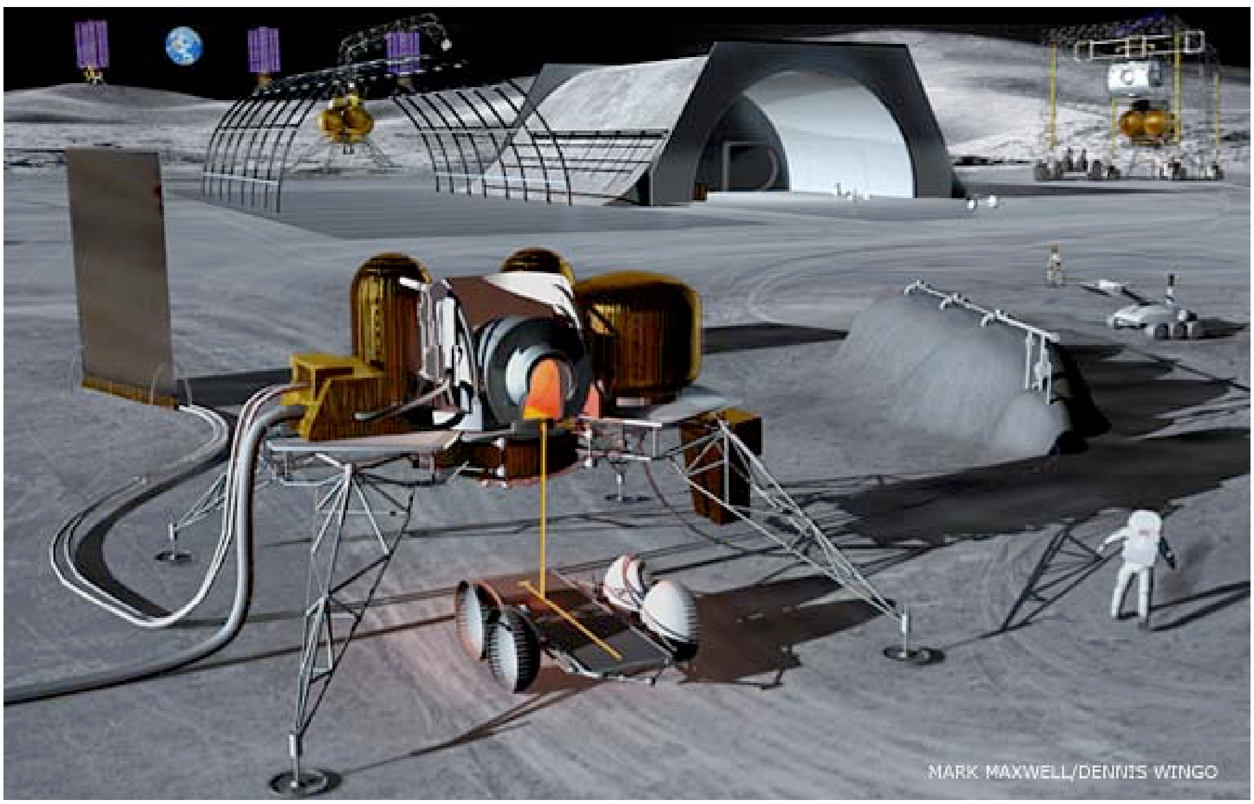
In 1991, another Augustine Commission came out with a set of recommendations. These fell by the wayside as did all of the other study groups and Presidential commissions, from Tom Stafford's Synthesis Group, the Aldridge Commission, the Space Task Group, as well as other less well known panels. Today's new Augustine Commission is looking at space yet again. Will this the product of their efforts be yet another report that is nothing more than fodder for space historians? As a group, Gordon, Paul, and I felt that we had to speak with a common voice to reach out to our community and to the Augustine Commission to say that there is more out there than rocket designs. We can do more, within the limitations of existing budgets. We represent two generations of space advocacy and professional experience. We have seen these plans and architectures and new launch vehicles come and go without a focused goal or real results.

We can open the space frontier to make significant contributions toward helping solve the problems that confront us on Earth. ISRU can help us with things as mundane as dealing with environmental waste on a global scale. Learning to extract metals from rocks can help us come up with mining methods that are more environmentally friendly and more efficient on Earth.

The development of new robotic systems that will be force multipliers on the Moon can contribute to balancing the advantage of cheap labor that other countries have in manufacturing. By implementing advanced solar power systems on the Moon, we can improve solar power systems on Earth. There are possibilities toward finding extraterrestrial materials on the Moon that may be of value on Earth as well.

As Robert Zubrin so eloquently stated about Martian development, the most important developments are the ones we don't know about yet and will be invented as part of the pressing needs of developing the Moon. Mars? With a lunar space port and the ability to build large hardware there, Mars becomes much closer than it will ever be by focusing on developing new heavy lift launch vehicles on Earth. That much is evident by the past 37 years of our failure to move humans beyond low Earth orbit.

The future is beckoning and this vision (defined as "sense of purpose") can be realized within the budgets of today. As the Apple Computer motto has it, we just need to "Think Different."



Concept Spaceport/Settlement Under Construction in Lunar Polar Region (picture by Mark Maxwell, copyright Dennis Wingo)