THE CHALLENGES AND BENEFITS OF LUNAR EXPLORATION

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Abstract

Three decades into the Space Age, the United States is experiencing a fundamental shift in space policy with the adoption of a broad national goal to expand human presence a nd activity beyond Earth orbit and out into the Solar System. These plans mark a turning point in American space exploration, for they entail a shift away from singular forays to a long-term, evolutionary program of exploration and utilization of space. No longer limited to the technical and operational specifics of any one vehicle or any one mission plan, this new approach will involve a fleet of spacecraft and a stable of off-planet research laboratories, industrial facilities, and exploration programs. The challenges inherent in this program are immense, but so too are the benefits. Central to this new space architecture is the concept of using a lunar base for in-situ resource utilization, and for the development of planetary surface exploration systems, applicable to the Moon, Mars, and other planetary bodies in the Solar System. This paper discusses the technical, economic, and political challenges involved in this new approach, and details the latest thinking on the benefits that could come from bold new endeavors on the final frontier.

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I am pleased to be with you today, and honored to open this first session of what I am sure will be an exciting Lunar Materials Technology Symposium.

I would like to talk with you about the broader issues which will, in the next few years, surround the work that all of you have come to Tucson to discuss. Thanks to your research, we have a very good idea of the kinds of processes, techniques, and industrial applications with which we will begin to utilize the abundant resources of the Moon. We know what is there, we have a fairly sophisticated view of where to look for it, and we are investing time and effort in developing the tools necessary for the job.

We can even tell the skeptics why. Several people who are here at this conference, and several others, have shown that the downstream economic return from renewed lunar activity could be profound, to say nothing of the scientific return from having research facilities on the Moon. So the entire notion of returning to the Moon and extracting oxygen and hydrogen, among other things, or of exporting solar power to the Earth, or extracting Helium-3 for the fusion reactors of the 21st century, is an entirely reasonable and doable enterprise to consider.

But, as the talents we have honed for the last thirty years are applied on the surface of the Moon, there will be a broader context of issues arising from the very nature of the endeavor itself. If the history of the Space Age can be our guide -- and I think it can -- the greatest challenge facing renewed lunar exploration in the future will be a combination of the political and the technical, and the greatest benefits arising from it will sweep across our entire culture. They will be societal in nature.

So, here at the outset, let us consider some of the larger implications of what a return to the Moon could mean. For the space program itself, it will be a turning point. After more than three decades of space exploration, the United States will be undertaking a fundamental shift in its national space policy. The goal will be to expand human presence beyond Earth orbit and out into the solar system. Such a plan marks a significant change for American space exploration because it entails a shift away from highly-focused, one-of-a-kind missions, such as Projects Gemini and Apollo, to a long-term, evolutionary approach to the exploration and utilization of space, along the lines of what we have just begun to do with the Space Shuttle and Space Station programs.

It will mean that we are no longer limited to the technical and operational specifics of any one vehicle or any one mission plan, and over time it will involve a fleet of diverse spacecraft and a stable of off-planet research laboratories, industrial facilities, and exploration architectures. This is pretty major stuff, in other words, and we should remember that, politically speaking, the place where the rubber will first hit the road is in the initiative to return to the Moon. Of course, there are some heavy questions associated with these things. Will the Congress support it? What kind of a line item will this be in the Fiscal Year '01 budget?

Clearing these political and budgetary hurdles; bringing new launch systems and space transportation vehicles on line; developing better methods for maintaining the health and productivity of flight crews; and learning to live and work amidst the extraordinarily hostile environment of the Moon are just a few of the challenges this effort will face. We should recognize that here is an enterprise that not only has to navigate in space, but also has to steer through that somewhat murky realm where capabilities, budgets, policies, politics, and the news media all meet. If I might

suggest an axiom here, it would be that the greatest challenges we face are not on the Moon, but in getting to the launch pad. We have to get the hardware on the launch pad first.

And we are talking about a great deal of hardware. Our best estimate is that in order to return to the Moon to set up permanent scientific and industrial facilities, we will have to be able routinely to place about a half-million pounds of equipment and provisions into low Earth orbit. Thus, the size, capability, and availability of launch vehicles becomes paramount -- and this is where history begins to repeat itself.

In the 1960s, the size of the launch vehicle was the same variable as today, having a profound ripple effect across the length and breadth of the Apollo program. In that era, the choice was between the Saturn V, capable of delivering 250,000 pounds of mass to low Earth orbit, and a much larger Nova booster, which would have been capable of lofting nearly 1 million pounds of mass into low Earth orbit. The selection of one or the other of the two boosters was related to a choice between three different approaches for sending humans to the Moon: direct ascent from the surface of the Earth to the surface of the Moon, Earth-orbit rendezvous, and lunar-orbit rendezvous. The eventual choice of lunar-orbit rendezvous matched it to the capabilities of the Saturn V.

In much the same fashion, the size of America's next-generation launch vehicle will determine the pacing and structure of renewed flights to the Moon, subsequent voyages to Mars, and our ability -- or inability -- to engage in the kind of resource utilization programs we have gathered here to discuss. For example, the geosynchronous orbit Solar Power Satellite (SPS) reference concept was closely studied by NASA and the Department of Energy from 1977 to 1980. Although the so-called reference concept was intended to show only conceptual and technical feasibility, it was reliant on an enormous launch and assembly capability that even today would seem many years in the future. The analysis in the NASA-OOE study was based on construction of two 50,000-ton satellites each year for thirty years, each of which produced 5 gigawatts of power on Earth. Under that plan, the heavy-lift requirement from Earth to low Earth orbit was calculated at eight 425-ton cargo shipments each week, or about 400 each year.

But the use of lunar materials to build even that reference system -- an option that could become more practical given the inherent capabilities of a country with the wherewithal to establish a lunar base -- would reduce by up to fifty-fold the number of launches required from Earth. Mining lunar materials to produce raw rock, fabricating finished products on the Moon, and then transporting all of that to geosynchronous Earth orbit for such uses as an SPS would have significant synergism with other activities we already know will have to be performed on the Moon as the exploration program proceeds. The launch hardware choices we make today, however, could greatly influence such capabilities tomorrow. The threads of the future will be woven about this kind of technical and political tapestry.

And then there are the societal implications.

The next question we should ask ourselves is: "What will a renewed program of lunar exploration mean for the people of Earth? What will be the effect on our society and our culture?" I think, first of all, that an overall change of perspective is likely, and while it will be of a fundamental nature, it also will have an intangible effect in many ways, and something the historians will be best suited to measure many years from now. But what do I mean by a change of perspective?

More than two thousand years ago, Socrates wrote, "Man must rise above the Earth, to the top of the atmosphere and beyond, for only thus will he fully understand the world in which he lives." In 1948, British astrophysicist Fred Hoyle wrote, "Once a photograph of the Earth, taken from the

outside, is available -- once the sheer isolation of the Earth becomes plain -- a new idea as powerful as any in history will be let loose."
I think Apollo 8 proved both men right. In December 1968, after a really tough year in Vietnam, the world experienced a few days of magic. During the Christmas season came the flight of Borman, Lovell, and Anders on humanity's first circumnavigation of the Moon. We sat entranced and watched views of the Moon and the distant Earth unfold that were breathtaking to behold, and on Christmas Eve the crew read from the Book of Genesis in the Bible. *The Washington Post*, in an editorial, said, "At some point in the history of the world, someone may have read the first ten verses of the Book of Genesis under conditions that gave them greater meaning than they had on Christmas Eve. But it seems unlikely.... This Christmas will always be remembered as the lunar one."

When the crew of Apollo 8 returned, they carried with them a precious set of images. Who can forget those views of the good and bountiful Earth, in gibbous phase, rising above the desolate limb of the Moon. That perspective changed our thoughts and our outlook on the Earth forever. One of those images was displayed just above Walter Cronkite's shoulder every night on the *CBS Evening News*.

American Poet Laureate Archibald MacLeish was moved to write, "To see the Earth as it truly is, small and blue and beautiful in that eternal silence where it floats, is to see ourselves as riders on the Earth together, brothers on that bright loveliness in the eternal cold -- brothers who know now that they are truly brothers." The rise of an ecological movement in this country, and the first observance of Earth Day in April 1970, is attributed by many to those photographs. John Caffrey of the American Council on Education wrote in the March 20, 1970, issue of *Science* that, "the views of the Earth from that expedition and from the subsequent Apollo flights have made many of us see the Earth as a whole, in a curious way -- as a single environment in which hundreds of millions of human beings have a stake. I suspect that the greatest lasting benefit of the Apollo missions may be, if my hunch is correct, this sudden rush of inspiration to try to save this fragile environment -- the whole one -- if we still can"

So that was the reaction more than twenty years ago. What can we expect in the future? How might our outlook evolve? Consider, if you will, a recent news story. I'm sure most of you have heard or read of the young man who recently announced that his father, who worked in the Apollo Program, had bequeathed him a small sample of lunar dust which came from one of the astronauts' space suits. The young man made news when he offered to sell the dust to the highest bidder in order to finance his college education. The suggested retail price of this dust was somewhere between $20,000 and $30,000.

In Houston, I saw a couple of articles each in the *Chronicle* and the *Post*, I know that the wire services reported the story, and in January, Larry King had the young man on his live CNN talk show. So this obviously did make some news, and was all the more interesting initially because NASA's chief legal counsel announced that the Agency took a dim view of private ownership of lunar samples, and the Inspector General promised to look into the matter.

The IG let the matter drop after a few days, and the young man was left to make his best bargain and pursue his education. However, the point here is that nowhere in the discussion did I ever hear anyone point out that the dust samples, from the perspective of a collector, are a very dubious investment in the first place. When you think about it, the point of collecting things and determining their value over time -- whether it be stamps or coins or comic books -- is based on their rarity. Generally, the rarer the coin, and the older it is, the more it is worth, and that worth keeps increasing as the years roll by.

Not so with lunar samples. They are very valuable now, because we and the Russians have acquired less than 900 pounds total, but if the endeavors imagined by all of us go forward, in not very many years we will be awash in the stuff. I would say that young man's lunar dust has a financially lucrative half-life of just a decade or two, which is not such a wonderful long-term investment.

Again, in large ways and small, the very existence of a program to explore the Moon will shape our outlook and our course as a great nation. And in this sense history offers some interesting perspectives. We live in interesting times. Today, February 20, 1992, for instance, is the 30th anniversary of John Glenn's historic first U.S. orbital flight. At the time, in the winter of 1962, this seemed the most extraordinary of technological feats. The youngsters of that day -- now known as the Baby Boomers -- became the first generation in history to view space flight as a complete reality of their time. When asked what they wanted to be when they grew up, they could respond, quite viably, "an astronaut." Today we are rearing the first generation in history to have access, from an early age, to the well-developed capabilities of the personal computer, camcorders, cellular phones, FAX machines, and Nintendo games. And we can only guess how that will affect their judgment, their talents, and their outlook thirty or forty years from now when they come into positions of responsibility and authority.

Another cycle of history takes fully two centuries to develop. It is the story of exploration and the opening of a new frontier, and comes to mind with the approaching bicentennial in the year 2003 of the Lewis and Clark Expedition. Actually, according to Gary Moulton, editor of the first new edition in almost ninety years of the journals of Lewis and Clark, "the roots of the expedition. . .were already lengthy by the time of the Louisiana Purchase in April 1803." For at least twenty years, since as early as 1783, Thomas Jefferson had been thinking about an expedition to explore the upper reaches of the Missouri River.

When he became President, Jefferson wasted no time. "It would be arbitrary," Moulton writes, "to distinguish between his 'practical' and 'scientific' goals, for Jefferson, a true son of the Enlightenment, believed all knowledge to be of some benefit." Their "Corps of Discovery," as it was called, was charged to "observe and record the whole range of natural history and ethnology of the area and the possible resources for future settlers." Jefferson also expected them to open a highway of commerce to the West. While the expedition was presented to the French and the Spanish as merely a scientific enterprise, the Congress authorized it under the commerce clause of the new Constitution. The expedition was funded by a $2,500 allocation from the War Department budget at a time when total federal expenditures, less debt repayments, amounted to $7.8 million. That is entirely analogous to a Voyager- or Galileo-class expedition today.

From the perspective of history, we can see that the journeys of Lewis and Clark had little immediate practical effect on the course of the nation. But those who read of their travels were excited, and the imagination of a young nation could begin to contemplate the realities of a vast, untamed frontier. Over time, this vision of the west took hold, but the development of a practical infrastructure to explore and utilize the frontier took another twenty or thirty years. Only in the 1820s, through such programs as Henry Clay's "National System," did the Congress begin to legislate internal improvements such as roads, canals, and developed natural waterways. And it was still another sixty years before the railroads joined the continent together.

In that time, of course, the great Indian horse cultures of the plains disappeared, and by the end of the 19th century the American frontier had passed into history. That sense of frontier, of elbow room and exploration, has for two centuries now been fundamental to the American psyche, to our ideas of ourselves and our national culture.

I think it is most compelling to consider this in light of our recent past. In many ways, the voyages of Apollo are analogous to the Lewis and Clark expedition. Now here we are, twenty years after Apollo, and the tides of government policy are steering us toward the development of an infrastructure to explore and to utilize the Moon we first surveyed. And in the end, of course, we will arrive back where we started, 200 years later. We will have an American frontier once again.

In closing, I would leave you with the perspective of Carl Sagan, who has written that, "in the long view, the greatest significance of space exploration is that it will irreversibly alter history, "

This is where the adventure will take us, ladies and gentlemen, and on behalf of all of us at the Johnson Space Center, we wish you well as you and we pursue that dream.