1 / THE SYMPOSIUM: KEYNOTE SPEECHES

FROM OCTOBER 29 TO 31, 1984 a NASA-sponsored, public symposium entitled "Lunar Bases and Space Activities of the 21st Century" was hosted by the National Academy of Sciences in Washington, DC. Approximately 300 attendees registered to hear 135 papers on a variety of topics relevant to space program goals in the era following establishment of the LEO space station. Since very little research on these issues is currently being funded, the many participants who traveled to the meeting tended to have a very personal, as well as professional, interest in the theme. As indicated by the title of the conference, the bulk of the discussion centered on lunar occupation, its implementation, and its implications. However, other future scenarios were not excluded; several contributed papers suggested manned exploration of Mars as an alternate or complementary long range goal.

To those unfamiliar with the state of space technology, discussion of colonies on the Moon and Mars have the ring of science fiction. Persuasive arguments are made within the pages of this book and elsewhere that permanent human presence in the space environment can be established and maintained within the bounds of contemporary technology. While technological capability is a necessary condition for a lunar outpost, it is not a sufficient one. Space transportation is still expensive and therefore achievable only by institutions with significant financial resources.

In all likelihood, private capital will not be invested in lunar development until near-term profitability is more than speculation. Similarly, public funds will not be spent until a clear case can be made in terms of the national interest. The nature of the national interest is complex, ranging from national security to stimulus of the private sector of the economy. For that reason, several individuals with experience in the formulation of national policy were invited to address the Symposium in the opening plenary session. Their views are particularly relevant to that part of the feasibility issue that addresses public investment in the future of society.

Mr. James Beggs is Administrator of NASA. Dr. George Keyworth is scientific advisor to President Reagan and directs the Office of Science and Technology Policy. Mr. Walter Hickel of the Yukon Pacific Corporation is former Governor of Alaska and Secretary of the Interior. Dr. Arthur Kantrowitz of Dartmouth College, former chairman of Avco Corporation, has in recent years been involved in studies of formulation of public policy with respect to technology. Dr. Edward Teller is a prominent nuclear physicist serving on the President's Science Advisory Committee.

Two keynote speakers chose to develop their remarks into more formal papers. Dr. Philip Smith, Executive Officer of the National Academy of Sciences, discusses the issue of international relations in the section Societal Issues. Dr. Harrison Schmitt, Apollo 17 astronaut and former Senator, looks at the implications of manned missions to Mars for national policy in the section Mars.

Remarks on the Lunar Base

James M. Beggs

Administrator, NASA/Headquarters, Washington, DC 20546

Over the years, the National Academy and its Space Science Board have played a pivotal role in NASA's advanced science planning. Our joint efforts have been extremely valuable in helping to chart a course not only for our future efforts in astronomy, astrophysics, and planetary exploration, but in the earth sciences as well.

Little by little, our efforts to explore space are becoming broader and more encompassing. Step by step, we are learning about the physical universe. By no means do we know all there is to know about the chain that connects the first appearance of the universe some 15 billion years ago with its evolution, the formation of matter, the galaxies, the stars, the solar system, the planets, and ourselves, but we are learning fast.

Our solar system exploration has been exceptionally successful and productive. We have observed the Sun from above the Earth's atmosphere; we have explored the Moon; by the end of the decade, we will have sent spacecraft to all of the planets except distant Pluto.

Ironically, we probably know more about Mars and Jupiter as respective planetary systems than we do about our own planet. We are just beginning to understand Earth as a system and the complex interaction of its various subsystems—atmosphere, oceans, natural resources—and the forces that built them and that determine their evolution and destiny.

Our goal on Earth, as in space, is to push scientific frontiers forward, to the cutting edge of understanding. In this effort, we are fortunate, indeed, that the Academy's Space Science Board recently agreed to provide additional guidance for NASA's long-term space science. During the next 2 years the Board will be undertaking a broad study of science priorities for the next 25 or 30 years and identifying the technology advances necessary to meet those priorities.

That effort is only one of several under way to help us define what we should be doing and where we should be going in space during the next generation. Another ongoing project is our internal NASA long-range planning study on post-space station options.

This symposium is still another timely effort to define where we should be going in space in the early years of the 21st Century. It follows closely the Lunar Base Working Group meeting, held last April at Los Alamos, which debated the pros and cons of establishing a permanently manned base on the Moon's surface. As you know, the

Working Group concluded that such a base should be adopted by NASA as a long-term goal for the 21st Century.

This goal has long been our vision, and it still is. Even before Apollo, our studies concluded that such a base could serve as a facility for scientific research, economic exploitation of the Moon's resources, and colonization of the Moon.

Today, more than 15 years after we first set our footprints on the Moon, we have learned much about it. Twelve Apollo astronauts walked on the lunar surface. They returned more than 2,000 samples of lunar rocks and soil from six locations. Soviet unmanned spacecraft have provided us with samples from three other sites. Spacecraft have photographed the entire Moon from lunar orbit and performed chemical analysis of more than a fourth of its surface.

Our lunar exploration revealed no water, no organic matter, and no living organisms, but the Moon rocks turned out to be lunar time capsules. They contain the secrets of more than four and a half billion years of lunar history, a history we are beginning to understand using radioactive measurement techniques. The lunar soil, more akin to fine, broken rubble, is teaching us much about our Sun because it has absorbed billions of years of its radiations, unprotected by any atmosphere. We know now that the Moon not only has plentiful oxygen in its rocks but also silicon and possibly valuable metals such as iron and titanium.

The Moon, our nearest neighbor in the solar system, is becoming a familiar place. For more than four billion years, it lay there, quiet and still. Today we are exploring the possibility of going back there to live and work, a truly extraordinary development in the short history of the space age.

I believe it is highly likely that before the first decade of the next century is out, we will, indeed, return to the Moon. We will do so not only to mine its oxygen-rich rocks and other resources but to establish an outpost for further exploration and expansion of human activities in the solar system, in particular, on Mars and the near-Earth asteroids.

One does not have to be an historian of the space age to recognize that a return to the Moon would be a rational extension of our program to expand human activities in space. From Mercury, and on through Gemini, Apollo, Skylab, and the Space Shuttle, we have moved steadily into larger and more ambitious programs. Each has been a logical extension of what came before, and each has been built on past experience.

N*ow that the space shuttle is proving to be the reliable and versatile machine its designers intended, we will use it to help meet our next major challenge: to develop a permanently manned space station in low-Earth orbit within a decade, as the President directed us to do.*

We expect that by the year 2000, the space station will be equipped with a supporting infrastructure that will enable us to operate routinely at both low-Earth and geostationary orbits and between them and, eventually, at distances as far as the Moon and the inner planets. Two key elements of this infrastructure will be reusable and might be compared to a local taxi and an intercontinental airline.

The former is called the Orbital Maneuvering Vehicle. It will be used to service satellites close to the space station and for other tasks. The latter, known as the Orbital Transfer Vehicle, will ferry payloads to and from geosynchronous orbit or launch spacecraft to the Moon and other points in the solar system.

Wernher Von Braun used to say that if people are ever to open vast uncharted regions to detailed exploration and permanent human habitation, they need an enabling technology. In the case of Antarctica, as Wernher rightly pointed out, it was the airplane. In the case of space, it will be the space station and its infrastructure.

This enabling technology will permit us to engage in a variety of manned and unmanned activities in space. It will spur exploration and the commercial use of space. It will invigorate Earth applications and stimulate sustained research and development on innovative systems and techniques. It could also trigger extensive initiatives to benefit life on Earth, such as satellite power systems and nuclear waste disposal systems in space. And it will be the key to future, more ambitious missions, such as a manned mission to Mars, the capture of an asteroid, or large, automated, deep space and planetary probes.

One of those missions, as I have said, could very well be the establishment of a permanently manned lunar base. That's why this conference is so important. It will help us move toward a national dialogue in the scientific and technical community on the uses, feasibility, and significance of a lunar base. It is essential to start such a dialogue now if we are to lay the groundwork for NASA's consideration of a long-range program plan to include a permanent human presence on the Moon.

These proceedings undoubtedly will be both stimulating and productive. And, as you continue your discussions over the next few days, you will be covering many crucial considerations—technical, scientific, political, economic, and social—that will guide future public policy decisions on a permanently manned lunar base. I'd like to single out just three, because they symbolize both the philosophical and practical realities of this new era of opportunity in space.

First, a whole generation of people is coming of age, not only in the United States, but around the world, who are barely able to remember that it was once thought impossible to go to the Moon. We now know that we can get there. The question is, what should we be doing if we establish permanent roots there to make our presence most productive and beneficial for mankind?

Next, we know that any enterprise of the magnitude and scope of a permanently manned lunar base would be an enormous challenge. We would have to develop not only new technologies, but the managment techniques and economic analyses that would make it both feasible and profitable. This implies even greater international cooperation and international sharing of risks and benefits in the future.

In this connection, we expect our friends and allies to accept President Reagan's invitation to join with us in developing the space station. Such cooperation could lay the groundwork for even greater international collaboration in space for the future. Indeed, an internationally developed lunar base might prove an irresistible lure to the Soviets. And, if they were to join with us, I believe that it would certainly enhance the prospects for peace in the world and in space.

A third consideration is technological. If we were to mine the Moon, how would we go about it? Many methods have been proposed, but none have been proven.

At present, we know how to extract valuable materials from ore deposits on Earth. But Earth's ore deposits are unusual, in that their valuable elements are highly concentrated and relatively easy to extract. Moon rocks and meteorites are different. Their key elements are not concentrated and are hard to extract. We have no Earth-based technology at present that could do the job.

Clearly, such a technology will have to be developed if we are ever to mine the Moon. That's why we should begin soon, on a small scale and in a preliminary way, to study how to extract useful minerals from lunar rock and soil. In space, as on Earth, there are rich dividends and enormous benefits for those who are able to muster the resources, know-how, and vision to follow where their dreams may lead.

On September 16, 1969, Astronaut Michael Collins closed an extraordinary chapter in his life and in the history of the world—the Apollo 11 mission—with these words before a joint session of Congress:

> We have taken to the Moon the wealth of this nation, the vision of its political leaders, the intelligence of its scientists, the dedication of its engineers, the careful craftmanship of its workers, and the enthusiastic support of its people.
>
> We have brought back rocks, and I think it is a fair trade . . .
>
> Man has always gone where he has been able to go. It's that simple. He will continue pushing back his frontier, no matter how far it may carry him from his homeland.

Mike's words sum up as eloquently as any the opportunities and challenges that lie ahead. If we are to be true to our own past and our own future, we will continue to pursue them.

The Challenges and Opportunities of a New Era in Space: How Will We Respond?

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Now, more than at any time since the dawn of the space age a quarter-century ago, we're poised at the edge of great advances in our understanding and use of space. Twenty-five years ago we rose magnificently to the challenge presented to us from Sputnik. In barely more than a decade, we created a wholly new technology—the technology of space travel and space exploration.

In the 1970s, the decade that followed, we consolidated our gains and refined the technologies. We started demonstrating that we could develop increasingly reliable technologies—both manned and unmanned—to operate in that new environment. What had been solely a government venture began to become attractive to the private sector, and soon that attractiveness turned to profitability, particularly with the proliferation of communications satellites. I would characterize the development, and now almost routine operation, of the shuttle as the beginning of the mature *phase of our early space technologies. We've now achieved a degree of confidence and predictability in space operations that gives us a calculable basis for considering investment in space enterprises.*

The real question now is where we go from here. Are our grand exploring days just beginning? Or will we devote our efforts from now on to consolidating our gains and expanding the commercial applications of space technologies? Or will we do both?

Just four or five years ago we might well have answered that question differently than we would today. I doubt, for instance, that this meeting could have taken place in the atmosphere of those days. Five years ago, the country as a whole was in a trough. Our industries were encountering competition of the sort they had never seen before—competition from foreign firms in the very high technology areas we had always dominated and taken for granted. The Japanese had discovered that Japan was a great place to make cars and televisions and that America was a great place to make money. American companies had good reason to wonder what the future would bring them. At the same time, government had let our leadership in science and technology begin to erode by failing to invest in the basic research that underlies so much of our progress in today's world. That hardly encouraged industry to count on glowing prospects for technological innovation in the long term.

Perhaps worst of all, we were 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.

That was five years ago. You may have noticed some changes in attitude since then. American business is just as respectful of the foreign challenge as ever, but it's no longer paralyzed by irrational fear, and it's planning for the future with the confidence of people who are determined to meet any challenge. The federal government, during the five years of the Reagan Administration, has turned that decline in support for basic research into the greatest rate of growth since the early post-Sputnik years, an increase of 55% in four years. Our universities are well on their way to regaining the health that had been jeopardized, and there's a strong renewed commitment to excellence in education, especially in science and math, in our public schools. No one is talking any more about limits to growth.

So what better time could there be for a conference like this? I said earlier that there are two paths our space program could take at this point—the practical and the visionary—and I asked which we would choose. My firm opinion is that we have to follow both *paths aggressively. That's why we're now seeing federal agencies other than NASA assuming responsibilities for commercializing space activities. That's the best evidence that you'll see that we intend to reserve NASA for what it does best: research and development. I'll add my firm belief that only by continuing to push at the boundaries of that vast space frontier will we be able to assure our world leadership in the relatively more mundane practical space technologies. In a very real sense, the economic future of space is tied to how much we stretch our vision and creativity to respond to the grand challenges.*

Some of you may have read President Reagan's response in this month's Omni *magazine when he was asked the question, "What interests you about space?" His answer sets the tone for this conference better than anything I could say:*

> What interests me about space is quite simple; space is a part of the future, of a future that captures the imagination of young and old alike. Think of the remarkable achievements of the American Space Program—the manned Moon landings, Viking's landing on Mars, the spectacular Voyager missions to Jupiter and Saturn, the continual rediscovery of our own planet, and the space shuttle, with its many important scientific achievements.

> In what other areas have American science and technology succeeded so well in literally moving us from one age to the next? Our space successes have proved that although all but a handful of us are physically bound to the Earth, our spirits and our national pride can soar along with astronauts and spacecraft. To me, that's the ultimate attraction of the space program—the elevation of the human spirit as we demonstrate our unmatched capability to reach out to new worlds.

It's that context, one of a whole people reaching out to new worlds, that should underlie these discussions of a manned lunar base. Today's new era of competition, of commitment to excellence in science and technology, and of development of the new talents we need for the future, demands and will support *new space initiatives if they match the boldness of our times.*

Today we stand on the threshold of that boldness. We need only create a door that opens out on this new world of challenges and opportunities that space offers us, and, last January, President Reagan committed the nation to building that doorway in the form of the manned space station.

Well, what possibilities wait for us when we step through that doorway into the next space age? I think we can begin to see that future at this conference, because the lunar base is one of the more obvious of the bold, exciting goals we can reach through the space station doorway.

In looking at the program that Mike Duke and the others have put together, I was excited by the diversity of the topics and the expertise of the participants. Either the planetary science community is farther along in its thinking about a lunar base than more people give it credit for, or this conference itself is providing a potent stimulus to thought. In either case, this conference is probably going to be remembered as a landmark in the evolution of thinking on the subject.

But as you listen and talk over the next three days, or afterwards, I'd like for you to ask yourselves two questions that I think will help to develop the concept of a lunar base as a possible national initiative. The first question may seem presumptuous, but I think we have to ask, right at the outset, where we go from *the lunar base? What steps should we be taking in parallel with the lunar base, and what comes after it? Do we go to Mars, and if so, why? Do we try to visit an asteroid? Remember that much of the momentum of our space program was lost after Apollo because we treated the Moon landing as an end in itself. This time we should know enough to define and update our goals in space in broad terms related to our future, not in terms of individual projects. And we should cast as wide a net as possible in creating this vision of our future, involving the American public and being driven by their enthusiasm as well as our own.*

Now, if my first question seemed presumptuous, then my second one may seem backward, but try it on anyway. How would a base on the Moon affect life on Earth? Again, let's remember Apollo and how it changed our concept of stretching our horizons. I think those of us in science often fail to understand the impact on society as a whole of well-defined and clearly articulated goals. Scientists, of course, don't need much encouragement to beat a path to a frontier. After all, little more than a hint *of a new subatomic particle will send my fellow physicists off on years of day-and-night dedication at some microscopic frontier, just as geologists will devote lifetimes working at the macroscopic frontier of piecing together the patterns of the movement of continents. But mere scientific curiousity can't hold a candle to the kind of inspiration that space has provided to our nation. It's hard to think of any peacetime program that ever inspired a nation's imagination and enthusiasm the way the Apollo program did—and that's the spirit that we should be trying to generate in tomorrow's space program.*

Let me add that both those broad inspirational benefits and the attraction of space as a scientific frontier have a very tangible counterpart. Space can be the kind of intellectual and technological endeavor that attracts the best young minds in our country and challenges their creativity. The response to those challenges, in the form of innovation and new technologies, will help keep the United States at the forefront in science and technology—and will strengthen our ability to compete aggressively in the world marketplace.

In spite of our best efforts to detail the spinoffs and benefits from the space program, I don't think the chief *benefit of Apollo can ever be quantified. That benefit was a glorious elevation of the human spirit and of national pride, a reminder that our society, giving free rein to human creativity and enterprise,* can *achieve herculean goals if it's challenged to do so.*

That kind of inspiration doesn't come along very often, so it's the kind of fire to keep burning. In an age of fierce and growing competition in the world commercial marketplace, there's no inspiration I'd rather be able to pass on to the youth of our nation. In fact, I can't think of a more eloquent statement of that idea than the President offered earlier this year when he spoke to the graduates of the Air Force Academy. He said, "Our willingness to accept the challenge of space will reflect whether America's men and women today have the same bold vision, the same courage and indomitable spirit that made us a great nation . . . The only limits we have are those of our own courage and imagination. And our freedom and well-being will be tied to new achievements and pushing back new frontiers."

To me that's the real theme of any conference on space—the fact that it challenges our vision today and will challenge it for as long as we can imagine.

In Space: One World United

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In the next few days you're going to hear a group of learned individuals address the prospects of permanent habitation of space. The experts will consider what tools we might take with us, what resources we might find out there, and what we might bring back to the Earth that is useful. Yet before we get into those details, I want to talk with you, as a layman, about the nature of frontiers and big projects in general.

Frontiers summon the creativity, imagination, and inventiveness of the human mind to conquer them . . .and in this age, the big project is the means to do so. A big project is what you get when you ask for the Moon. We called the first project Apollo. Today we're no longer just asking for the Moon; we've been there. We're looking further—to begin living outside Earth for good, wherever opportunity, curiosity, and need will take us. Our goal is more than another big project. It's time to open up the final frontier, permanently, to the point of no turning back. Our journey is really infinite, and a big project is what civilization needs to begin this journey and perfect the commitment to go beyond.

Big projects don't start with a lot of money. They start in the mind. Obviously, then, our journey begins here on Earth. We need to remember we're not here on this Earth just to be a user. We were made in the image of a Creator, and we're here to create. When we create, we explore the frontiers of the mind and the soul, for we must first acknowledge and open our inner frontiers before we can approach the outer frontiers of space. Charles DeGaulle once said, "We may well go to the Moon, but that's not very far. The greatest distance we have to cover still lies within us."

Thus, the immediate challenge before us now as Americans is to allow ourselves frontiers again. The parallel challenge is to train ourselves to bring about the big projects necessary to explore those frontiers. Candidly, we've been lagging on both fronts.

Frontiers have nothing to do with a coon-skin cap and a rifle. They have to do with limits . . .things we set for ourselves. You either believe in limits or you don't. Lately, we've only begun to emerge from a time in our history when many people believed economic growth on Earth has natural, predictable limits. Just a few years ago, we believed we were running out of everything. Many even ruled out hope. Frontiers were forgotten. About the same time in our history—ten years or so ago—America lost enthusiasm for its space program. The country began looking inward and became uncertain of itself.

I remember giving a series of talks in 1976 at the University of California. One of them talked about "the inexhaustible Earth." I believed then, as I do now, that the Earth is inexhaustible because God made man's mind inexhaustible. As long as we don't run out of imagination, we're not going to run out of anything. As I was saying that, a man in the audience scoffed. "Don't you know we're even running out of cement?" he asked. Imagine that. He seriously thought there was a shortage of cement. Cement—sand and gravel, ash and limestone!

Frontiers have always existed, and they always will. We approach a limited world with fear, but an infinite universe with confidence. A frontier is where you live with more questions than answers. You make decisions with your gut and your heart because your head can't help, but the important thing is to make those decisions: to go and to stay. Those left behind won't understand why we go or why we stay. But when a leap of faith is coupled with confidence in the future, progress results and all mankind benefits.

In the next few days we will probably hear more questions than answers. But let's respond with a decision. Let the questions point the way, not stop us from going.

In most businesses, it's the inventors, the scientists, the most knowledgeable people associated with a project who advocate moving forward the quickest. Politicians and external business forces usually act to slow things down. The space program, since the days of Sputnik, has seen just the opposite. Here, scientists are cautious in their advocacy. It takes politicians, and sometimes a national crisis, to speed things up.

Today we don't have a crisis. We just have an opportunity, and if the believers who are knowledgeable about space aren't advocates, how can we expect the non-believers to be? No one in this room should wonder if we're going too far, too fast in discussions about settling the universe. How can you go too fast when where you're going is infinite? I submit you can't go fast enough! And while I'm concerned that America is lagging in its space pioneering thinking these days, I believe we also need to examine our ability to undertake the big projects necessary to approach that frontier.

Look at the megabillion dollar projects on our plate right now. As an engineering society, we're performing miserably. Hesitation and indecision are the roots of the problem. America's nuclear power program is substandard to France, Japan, and Korea, in part, I believe, because we've refused to standardize. We're left with billion-dollar flower pots, many just close to being completed, that will never produce nuclear power. It seems that we can control the atom, but we can't control our costs. I entered a business recently to see that a $20 billion pipeline project is built across Alaska. The last group who tried spent $600 million before deferring construction indefinitely. They spent $600 million on paperwork . . .and there's still not a piece of pipe in the ground. There's a dam on the *drawing board in Alaska right now that has more than a hundred million dollars in it—and yet the state has yet to make a decision to build it. As a newcomer to the details of the space program, I was appalled to find out that we've dismantled the tools, and more importantly the collection of minds, that can produce a Saturn rocket.*

America, we can't do business this way. Civilization needs big projects, the kind that ignite the mind and inspire the soul. Remember, only eight years elapsed between Alan Shephard's first space flight and Neil Armstrong's first step on the Moon. We got there because John F. Kennedy made a decision. Big projects need decisions, not dollars, to get started. They need continuity and commitment. Civilization could never afford to spend billions of dollars dabbling in this or that . . .leading everywhere and going nowhere. It's jump or don't jump. Do it or don't.

Consider wars for a moment. Wars unite. They forge alliances among allies. They force an urgency of focus. They forge a common purpose, and they mobilize a will to achieve that purpose. But the fruit of war is destruction. Nevertheless, a war is a decision. We can go for years looking at ways to clean up our cities, but drop a bomb—or have an earthquake—one day, and suddenly we're cleaning up and building the next.

Decisions telescope time. I saw one space scenario recently, a planning document that moved us forward from a space station in 1991 to a lunar base in the year 2000 to a landing on Mars in 2030, forty-five years from now. That plan was made without a decision. I'm not an expert, but many of you are. Let me ask a question. How much further could you move in just ten years if we gave you a mandate?

For those of you who make your livings on the prospects of space exploration and development, I join you today as a kindred spirit. Forty-four years ago, as a Kansas farm boy, I went west, looking for a country. Going north, I found it, in Alaska, with enough opportunities to last many lifetimes. As I arrived, there were people leaving. Many of them felt that everything that was going to happen had happened already. Their frontier was over, because they never had one. But we believed in Alaska. We really believed.

We put together an economic base from the oil discoveries that were made by pioneering companies. Next came a megaproject that rivaled the costs and the organizational challenge of Apollo. We built a nine-billion-dollar oil pipeline eight hundred miles across virgin territory. It required new technology, new ways of doing business. But it worked, because a decision was made to do it.

Still, we've really only started. Flowing out of the ground with the oil is natural gas, almost as much in energy value. Our challenge today is not only to build another pipeline—the world's largest private project—but also to bring four nations together in this enterprise. In the maturing of Alaska, we depend not just on America, but on Japan, Korea, *and Taiwan, who must trust enough in the future to buy the gas and join the project. So, as we embark on the frontier in space, we might benefit from the experiences of one of the great frontiers on Earth.*

The arctic regions and the Moon have much in common. They're both remote. Not everyone understands living there. They're both rich in potential, potential that requires bold decisions to realize . . .but life is exciting and beautiful nevertheless. Leaps forward are made on the infrequent occasions when the decisionmaker has vision and isn't protecting the status quo. Decisions start with believers who really believe.

In starting most things anew, long term development thinking is absolutely necessary. Think of a child. If I had to pay someone to do what my wife did to bring up our children, waiting for a return on our investment with compound interest, no child would be economically feasible. During the next few years there will undoubtedly be continuous debate over whether or not living in space makes economic sense. I contend it won't make sense unless civilization commits to build a railroad.

Alaska's history provides an excellent example. We had a delegate to Congress in 1914 named Wickersham. He knew the territory needed a railroad. The richest private interests in the world had tried and failed to make it work. However, Wickersham was a believer. He convinced Congress not to seek a return on the railroad right away. The nation would get its returns from everything else the railroad made possible. The bill that passed authorized the President to build up to a thousand miles of rail, "its primary purpose to open up the country." Today, our civilization needs to make a similar commitment to build a railroad into space to begin to open up the universe. We need similar champions to tell us where we are.

Buzz Aldrin called the Moon "magnificent desolation." Its long term value may not be what it is but where it is.

I've talked about infinite thinking that establishes frontiers. I've discussed essential decisions that bring big projects about. There's one final thought I'd like to leave with you. In these discussions, the question of international cooperation has always surfaced. In my mind, it's no issue at all: leaving the Earth can unite us.

The President recently talked about sharing "Star Wars" technology with Russia to help free civilization from the threat of nuclear holocaust. We should ask the question, couldn't civilization also benefit by our united effort in the exploration of space? Should we ask the Russians to join us in going to Mars, and beyond?

Leaving the Earth can unite our purposes and peoples . . .our energies, talents, and technologies . . .and especially our minds. The exploration of space may well be civilization's last chance to join together in a great undertaking bigger than any of us—technologies for a common purpose, a great undertaking that can heal the divisions *between men—as together we seek to go vast distances, and yet, to cover those inner distances that yearn for explanation.*

Like a small boy asking, "Mother, what's out there?" let's join together and find out. What difference does it make which political party is in power or whose ideology is in vogue when we finally find God and the universe among us?

Good luck and Godspeed.

An Opportunity for Openness

Arthur Kantrowitz

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We are gathered to discuss a momentous undertaking. A lunar base would certainly begin a new chapter in world history. With a lunar base, humanity would for the first time be in a position to utilize extraterrestrial matter (ETM). Many important civilian uses for ETM will be dealt with in this symposium. In view of today's level of international tension, the application of large quantities of ETM in the hardening of space-based military assets inevitably comes to mind. What could this new capability imply for the debate now raging around the stability of Mutual Assured Destruction and the President's Strategic Defense Initiative (SDI)?

Several prominent scientists have come forward with negative theorems about SDI, easily produced and loudly announced, and at least partially based on the fragility of today's spacecraft without including the possibility of ETM. Perhaps on this occasion we should point out again that they really should have announced only that they *did not see how an effective strategic defense could be built.*

The threat of nuclear Armageddon has darkened the world for decades. To escape the darkness, arms control is usually offered as the world's only hope. It provides an opportunity for dialogue, and talk is safer than the alternatives. But verifiable arms control has a problem that must be faced. Starting with the tens of thousands of existing nuclear weapons, it may well be true that it is easier to verify adequate compliance with a freeze or a reduction agreement than to hide evasion. But hiding evasion gets progressively easier and verification gets progressively harder as the numbers are reduced, and the numbers must be reduced by a factor of thousands to bring us back to the destructive capabilities of WWII. While the dialogue on arms control must be pursued, we must not let it blind us to other possibilities, perhaps now only barely perceptible, for escaping the darkness.

*Arms control is the control of hardware. I would like to discuss a software possibility. In an instructive recital of the dismal history of arms control (*New York Times*, April 18, 1982), Barbara Tuchman quoted Salvador de Madariaga (Chairman of the League of Nations Disarmament Commission) as concluding that ". . .Nations don't distrust each other because they are armed; they are armed because they distrust each other."*

I find Madariaga's proposition exciting because it provides a new light in which to view a striking exchange on SDI in the recent presidential election debate. In response to a *question concerning sharing ". . .the best of America's technology with our principal adversary," the President began his answer with "Why not?" Mondale declared it was ". . .in my opinion a total non-starter."*

Following Madariaga's emphasis on the primacy of trust, a good way to judge a new military technology or policy in the nuclear age would be: Can it help nations to trust each other?

Surveillance satellites pass this difficult test, and indeed they constitute an important stabilizing influence in the present tension. Competitive deployment of a BMD system on the other hand is violently destabilizing. It is just this frightening destabilization that impelled Reagan to offer a new openness. This new openness could indeed help nations to trust each other. It could be the first light of dawn.

Technological change drives social change. Remember the trauma of the early industrial revolution and William Blake crying out against ". . .dark satanic mills." In just those countries and in just those times, the most open societies the world has ever known were growing. Openly published science soon left magic and its secrets far behind. Industrial competitiveness forced a transition from arts passed secretly from generation to generation to the mass education needed for a technological society.

In contrast, let me tell you briefly a story of rejection of a new opportunity for openness that occurred in early Ming Dynasty China. In the massive scholarly work Science and Civilization in China *(Cambridge, 1971, Vol. 4, Part III, pp. 392–535), Joseph Needham recounts the spectacular rise and fall of Chinese naval power. Up to the early 15th Century A.D., Chinese technology led the world. In his utopian* New Atlantis, *Francis Bacon exhibited three great inventions—printing, gunpowder, and the compass—as evidence that humanity could advance beyond the heights reached in antiquity. These were the foundation of his wonderfully fruitful proposal for the organization of applied research. Needham points out that these remarkable inventions were all well-known in China centuries before they appeared in Europe.*

In the early Ming Dynasty, this flowering technology culminated in a remarkable series of naval expeditions made by fleets of 1500-ton "treasure ships," each able to carry about 500 men. In the early years of the 15th Century, these fleets sailed around Southeast Asia to Bengal, Ceylon (from which they brought back a defiant king as prisoner) and finally down the east coast of Africa in 1420. About fifty years later, in a similar adventure, the Portugese sailed down the west coast of Africa in a series of voyages that opened up a new chapter in world history.

China made its last great voyage in 1431–33. According to Jung-pang Lo, in 1436, when the Cheng-t'ung Emperor came to the throne, an edict was issued that not only forbade the building of ships for overseas voyages but also cut down the construction of *warships and armaments ("Decline of the Early Ming Navy,"* Oriens Extremus, *Hamburg, 1958, Vol. 5).*

What changes took place with such repressive effect that China recoiled from its seaward expansion and career as a naval power? "This was, indeed," says Needham, "but one aspect of a general decline which reflected itself severely in many branches of science and technology. The navy simply fell to pieces."

After that happened, China lost its leadership in technology and isolated itself as long as it could from the explosive growth of Europe. This isolation became impossible when the military strength of the "barbarians" forced itself upon the Chinese in the Opium Wars four centuries later.

This was only one episode in a great administrative battle waged for thousands of years between the Confucian scholars who led the bureaucracy and the Grand Eunuchs of the Imperial Court. The eunuch Admiral Cheng Ho had led the last great voyages, and clearly their spectacular successes constituted a great threat to the power of the scholarly bureaucracy. But the scholars had a trump card—they had exclusive control of the education of the next emperor. Thus when he came to the throne, one of his first acts was to destroy the navy, and with it he destroyed China's leadership in technology. The scholars had argued that China had no need for contact with the rest of the world. The bureaucrats, by stopping technological advance, maintained their feudal power.

Technological change forces social change. Nuclear weapons, access to space, information technology, and genetic technology constitute great and threatening technological changes. What social changes are they forcing?

I will hazard a conjecture. Technological advance will continue to force us to a more open world. The SDI hardware, even if completely successful, would only protect us from ballistic missiles, but the increased trust, the new openness, that could come from cooperating with the Soviet Union and the world in a massive technological undertaking would have much more far-reaching effects. It could move us toward a world in which any secret enclave that could hide weaponry will be seen and dealt with as an aggressive act. It could help to create a world open enough to prevent all varieties of nuclear terrorism.

Thoughts on a Lunar Base

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I would like to start with a statement that I expect, and even hope, may be controversial. I believe there is a very great difference between the space station now being planned and any activity on the Moon now under discussion. I believe that in the space station we should do as much as possible with robots for two simple reasons. There is nothing in space—practically nothing—except what we put there. Therefore, we can foresee the conditions under which we are going to work, and, in general, I think robots are less trouble than people.

The other reason is that, apart from experiments and special missions that we have in space, we do not want to proceed to change anything in space, whereas on the Moon we will want to change things. Likewise on the Moon, we will find many things that we do not expect. Adapting robots to all the various tasks that may come up, and that we do not even foresee, is not possible.

The space station is obviously extremely interesting for many reasons. However, that is not what I want to talk about except to state that, of course, the space station is apt to develop into a transfer station to the Moon. Therefore, its establishment is not independent of what we are discussing here.

I would like to look forward to an early lunar colony. I do not want to spend time in making estimates but simply want to say that it would be nice to have a dozen people on the Moon as soon as possible. I think we could have it in ten years or so. When I say 12 people, I do not mean 12 people to stay there but to have 12 people at all times, to serve as long as it seems reasonable. To me, 3 months is the kind of period from which you could expect a good payoff for having made the trip. Longer rotations than that might be a little hard, and efficiency might come down. But all this is, of course, a wild estimate on my part.

What kind of people should be there? It will be necessary to have all of them highly capable in a technical manner, and I believe that they should perform all kinds of work. Probably at least half of them, after coming back to Earth, should get the Nobel Prize. The result will be that we will soon run out of Nobel Prizes because I believe there will be very considerable discoveries.

Also, if you have 12 people you probably ought to have a Governor. I have already picked out the Governor to be, of course, Jack Schmitt. Furthermore, I would like to tell you *that when I first testified about space, and was asked whether there should be women astronauts, I proposed that all astronauts should be women. The packaging of intelligence in women is more effective in terms of intelligence per unit weight. However, in view of the strong sentiment for ERA, I think I might compromise with an equal number of women and men. That arrangement has all kinds of advantages.*

I believe that the discussion here has had plenty of emphasis on what I know will be the main practical result of a lunar base—use as a refueling station. It will supply both portable energy in a concentrated form and portable fuel for refueling rockets, primarily in the form of oxygen extracted out of lunar rocks. The only question is how to do it. My first idea was, of course, we should do it with nuclear reactors. Perhaps the environmental movement, the Sierra Club, may not have an arm that extends beyond one light second. On the other hand, we will have some problems, problems of cooling. However, most of the energy might be needed to squeeze oxygen out of iron oxide, and that simply means a high temperature. You may not need a lot of machinery, and some of the energy can be, in this way, usefully absorbed right inside the reactor. What remains probably should be converted to electricity.

The other possibility is solar energy. I am strongly inclined to believe that solar energy will be quite useful for two reasons. First, great advances have been made in solar cells, particularly with regard to Ovshinsky's idea of utilizing amorphous semiconductors. The point is that they are not very good conductors of electricity and therefore must be thin, but, on the other hand, amorphous materials are very good absorbers of light and therefore can be thin. Methods to fabricate them have indicated that you can, with practical certainty, get down to one dollar per peak watt.

There is, however, another advantage to solar power and that is if you do not want power, but just want high temperature for driving oxygen out of oxides, you may not need mirrors that have to be moved. It might be sufficient to have the right kind of surface that absorbs and emits ultraviolet but is highly reflective in the visible and the infrared. In equilibrium with solar radiation, this will give high temperatures; the farther you go in the ultraviolet the more you can approach the maximum temperature obtainable, the surface temperature of the Sun. If you try to approach this limit, then the energy content—the power—will be small because it utilizes a smaller portion of the solar spectrum. But the temperature you can get is high. What the optimum is where you will want to compromise, I do not know.

Let me extend this idea one step further. I would not only like to get very high temperatures; I also want to get very low temperatures as cheaply as possible. You can achieve the latter during the 14-day lunar night. If you isolate yourself from the surface of the Moon, put your apparatus on legs and put some space in between—all very cheap *arrangements—you can approach temperatures in the neighborhood of 2.7 degrees Absolute. In this way you can get low temperature regions of large volume and high temperature regions of large volume.*

Now, I would like to talk about one practical point that may not have been discussed, namely, the question of where on the Moon the colony should be. I would like to go to one of the poles because I would like to have the choice between sunlight and shade with little movement. Furthermore, it would be a real advantage to establish the colony in and around a crater where you might have even permanent shade in some places and where moving away from the rim on one side or the other you can vary conditions quite fast. Of course, it is of importance not only to position yourself in regard to the Sun but also in regard to the Earth. For many purposes, you want to see the Earth in order to observe it. For other purposes, for instance astronomy, you want to be shielded from the Earth, not to be disturbed by all the terrestrial radio emission. All these conditions will be best satisfied in a crater near a pole.

I have a little difficulty in reading the lunar maps. There seem to be three good craters in the immediate vicinity of the south pole but no good craters near the north pole, or vice versa. *I am not quite sure. At any rate I want to go to the pole that has the craters.*

The purpose of all this is obviously what I have said to begin with and what you all realize—refueling and energy. Oxygen is the main point, but it would be nice also to have hydrogen. Hydrogen we could get from the Earth much more cheaply than the oxygen, but still it is one-ninth the cost of oxygen plus the considerable weight of the tank. Hydrogen has been deposited in the lunar dust by the solar wind over geologic time, and the mass of hydrogen in that lunar dust, as far as I know, is not much less than one part in ten thousand. Without having made a decent analysis, my hunch is that it is easier to move the lunar dust a few miles on the Moon than to come all the way from the Earth even though you have to move ten thousand times the mass. If you can distill oxygen out of iron oxide, you certainly can distill hydrogen out of the lunar dust. Furthermore, Jack Schmitt tells me that there is a possibility of finding hydrogen, perhaps even hydrogen that is four and one-half billion years old, in other parts of the Moon in greater abundance than what we see in the average lunar dust.

All of this is, of course, of great importance and perhaps serves as a little illustration of what kind of constructions we are discussing. Obviously, we will have to try to make these constructions with tools as light as can be transported from the Earth. In planning the lunar colony, special tools and special apparatus have to be fabricated on the Earth, specifically adapted to the tasks already described as well as others.

I would like to make a special proposal. I believe that surveillance of the Earth—permanent, continuous surveillance that is hard to interfere with—is an extremely *important question, important to us, important for the international community, important for peace keeping. There have been proposals, and I am for them, to guarantee present observation of facilities by treaties. On the other hand, treaties not only can be broken; treaties have been broken. It is in everyone's best interest to have observation stations that are not easy to interfere with.*

I would like to take the biggest chunks that I could get off the Moon and put them into a lunar orbit, perhaps 120 and 240 degrees away from the Moon. Of course, they will be very small compared to the Moon but maybe quite big compared to other objects that we put into space. If the Moon and these two additional satellites are available for observation, then we can have a continuous watch on all of the Earth with somewhat lesser information around the pole. The latter also can be obtained with additional expenditure, but to have 95 percent of the most interesting part of the Earth covered continuously would be already a great advantage. I would be very happy if, on these observation stations, we would do what we should have done with our satellites and are still not doing, namely, make the information of just the photographs obtained from the satellites universally available. I believe that would be a great step forward in international cooperation, international relations, and peace keeping.

Traveling to these artificial satellites from the Moon is a much smaller job than reaching them from the Earth. Since you stay on the same orbit, you just have to have a very small additional velocity after leaving the Moon, wait until you are in the right position, and then use a retrorocket. The total energy for that is small, and if you produce the rocket fuel on the Moon, then I think you have optimal conditions.

I also would like to have a satellite with a special property. It should have as big a mass as possible, built up from a small mass in the course of time. But, furthermore, I want it to rotate in such a manner that instead of turning the same face all the time to the Earth it should turn the same face all the time to the Sun. If you can do that, then half of the surface will be in permanent night, half in permanent illumination, and whatever we can do on the Moon, for instance setting up a permanent low-temperature establishment, you can do that very much better on these satellites.

Now, I would like to finish up by making a very few remarks on purely scientific work that will become possible. In the vacuum of the Moon we can work with clean surfaces. It is obvious that surface chemistry could make big strides. This can be done equally well in the space station, and, in this respect, the Moon does not have an obvious advantage.

Where you do get an obvious advantage is in astronomical observations where you want the possibility to collimate in a really effective manner. When you want to look at x-rays or gamma rays from certain directions, all you need to do is to drill a deep hole that acts as a collimator and have the detectors at its bottom. You would have to have a *considerable number of these holes, but I believe that it will be much cheaper than to have a considerable number of observation apparatus shot out from the Earth, particularly because the mass for collimation will be not available in space stations except at a considerable cost. The same holes may be used for high energy cosmic rays.*

Another obvious application is in high energy physics. As the size of accelerators kept going up, many years ago our very good friend Enrico Fermi at a Physical Society meeting, as far as I know, made the proposal in completely serious Italian style that sooner or later we will make an accelerator around the equator of the Earth. Well, we are approaching that—at least we are planning an accelerator that takes in a good part of Texas. I am not quite sure that we should do that. Let us wait until we get to the Moon. (That might happen almost as soon as a giant accelerator can be constructed.) We actually could have an accelerator around the equator of the Moon. Taking advantage of the vacuum available, you only need the deflecting magnets and the accelerating stations, and these can be put point for point rather than continuously.

I have been interested for many years in the remarkable discovery of Klebesadel at Los Alamos of gamma ray bursts that last for longer than 15 milliseconds and less than 100 seconds, have their main energy emission between 100 and 200 kilovolts, but seem to have components far above a million volts, too. I believe everybody is in agreement that these come from something hitting neutron stars and converting the energy into gamma rays. But most people believe that they come from nearby regions of our galaxy and are, therefore, isotropic. Actually the number of observations depends on the intensity in such way as though from more distant places we do not get as many as expected. The usual explanation is that we get these from farther places and we get them only from the galactic disc rather than a sphere. Unfortunately these bursts are so weak that the directional determinations cannot be made. On the Moon you could deploy acres of gamma ray detectors of various kinds and leave them exposed to the gamma rays or cover them up with one gram per square centimeter, five grams per square centimeter, or ten grams per square centimeter so that with some spectral discrimination you will get a greater intensity from perpendicular incidence than from oblique incidence. As this apparatus will look into the plane of the galaxy, into the main extension of the galaxy, or toward the galactic pole, you should see a difference, a deviation from spherical distribution, for these weakest bursts, essentially bursts of 10^{-5} *to* 10^{-7} *ergs/cm*^{2}*/s.*

A very good friend, Montgomery Johnson (who unfortunately died a few months ago) and I had made an assumption that these radiations really do not come from the galaxy but from outer space, from regions where the stars are dense and where collisions between neutron stars and dense stars like the white dwarfs may occur. Good candidates are the globular clusters, but there may be other dense regions in the universe as well. If *this hypothesis turns out to be correct, then the reason you find fewer events at great distances are cosmological reasons—curvature of space, a greater red-shift, lesser numbers of neutron stars and white dwarfs in the distant past, which was closer to the beginning of the universe. Actually, if this hypothesis is correct, then the gamma-ray bursts would, in the end, give us information about early stages of the universe. No matter which way it goes, the gamma-ray bursts are interesting phenomena, and the Moon is one of the places where they could be investigated with real success.*

I am sure that in these ways and many others an early lunar colony would be of great advantage.

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