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ESTABLISHING A PERMANENTLY MANNED BASE on the Moon is, of necessity, a large and visible exercise of engineering and technology. Some will see no more than that, but such a reductionist viewpoint misses the whole that is greater than the parts. A lunar settlement continues humanity's movement to accessible frontiers. It may start as a statement of national resolve or as a monument to international cooperation. It could be an heroic enterprise of epic dimensions or the stimulus for democratization of space through economic growth. One thing is clear—the Moon sits on the lip of the confining terrestrial gravity well and thus is the stepping stone to the solar system.

The space program blends a curious mixture of romance and pragmatism. Goals are set by dreamers and implemented by realists. Many of yesterday's visions have been realized, but the awe-inspiring accomplishments rest on carefully executed, often mundane contributions from tens of thousands of people. The inspirational and the commonplace are both aspects of the human condition to be reflected in the space activities of the 21st Century, and both are discussed in the contributions here.

Any grand achievement by society must begin as an expression of the ordinary processes of decision making. Logsdon, an experienced observer of the space program, looks at the initiation of past endeavors for clues to the key elements of consensus. The debate over allocation of public resources revolves around the worth and expense of any program. Sellers and Keaton analyze historical space expenditures in terms of the gross national product of the U.S. and predict the availability of funding for major ventures over the next two decades.

One school of thought on the worth of the space program sees space technology as a surrogate for military technology. On the theory that military expenditures are supported by the self-interest of a technology intensive industrial complex, competition in space is viewed as a peaceful replacement for competition in armaments. Alternatively, a large space endeavor can be a focus for international cooperation. The exploration of the solar system constitutes a politically neutral enterprise wherein new mechanisms for dialogue, exchange, and cooperation can be fostered. Smith draws on extensive experience with international relations in Antarctica to evaluate the prospects for cooperation on the Moon. Oberg, a longtime observer of Soviet space activities, comments on the possibility of an independent, competitive lunar project complementing a U.S. initiative.

Contemporary space law asserts that space, including celestial bodies, is not subject to national appropriation. Whether mining the Moon for use of its resources in space constitutes "appropriation" is not entirely clear. The "Moon Treaty," which has been ratified to date only by a few non-spacefaring nations, is much more restrictive in its provisions. Moore looks at implications of space law for proposed lunar initiatives. Joyner and Schmitt go one step further and propose new principles that could serve to extend existing legal mechanisms to allow investments in planetary development.

As technical capability increases and as more people work in space, management functions and eventual control of social structures must shift to the space facility from the Earth. Finney looks at living in space through the eyes of an anthropologist and urges the study of evolving social systems there as part of ongoing research. Lawler and Jones both present historical analogies where resource-poor colonies with long supply lines sometimes succeeded and sometimes failed.

To date, space travel has been the privilege of the few but the dream of many. Knox surveys expression of the soaring human spirit as it accompanies those first explorers to the frontier of space.

DREAMS AND REALITIES: THE FUTURE IN SPACE

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What factors must converge to create a societal commitment to creating a permanent human base on the Moon? There have been three major decisions to start manned space programs in the past 25 years—those which began Apollo, the space shuttle, and the space station. An examination of these decisions suggests that no one particular situation facilitates major commitments. Rather, a commitment results from the convergence of the political context; the goals of political leaders, particularly the President; the needs of various space institutions, particularly NASA; the success of earlier programs; and the options available at a particular decision point. While many of these factors are beyond the control of advocates of a lunar base, there are a variety of steps that can be taken over the next few years to improve the chances of program approval at some future time. However, advocates of a lunar base should recognize that it is unlikely that the political leadership will be willing to support another major space program until the space station is nearing operational status sometime in the 1990s.

INTRODUCTION

It is argued that "when the requisite technology exists, the U.S. political process inevitably will include lunar surface activities" (Duke *et al.*, 1985, p. 50). To a student of the political process, such an assertion of inevitability must be viewed with some skepticism, especially when it seems linked primarily to the existence of "requisite technology." It is important for those who want to see a "return to the Moon" goal accepted as an important aspect of future U.S. space policy to recognize that, while developing the requisite technology is a necessary condition for a lunar base program, it is far from a sufficient one.

What factors are essential for creating a political commitment to a lunar base? It is impossible to forecast, at least in specific terms. The United States government *has*, in the past three decades, initiated three major manned space programs—Apollo, space shuttle, and space station; thus it certainly is not impossible to organize and sustain a political commitment to a multi-year, multi-billion dollar enterprise in space, even though such politically supported undertakings are the exception rather than the rule in the United States. Initially, this paper explores these three decisions in order to identify their major characteristics; then, these characteristics will be compared in order to make some useful general comments on the conditions that might lead to the hoped-for commitment to a lunar base program at some future date.

Apollo as a Crisis Decision

In times of crisis—situations that allow only a short time for response without extensive prior planning and where the issues at stake are of great importance—many of the barriers to rational, "top-down" decision-making disappear. Such a situation occurred in April, 1961 (Logsdon, 1970). The self-image and international standing of the United States had been stung in rapid succession by the success of the Soviet Union in orbiting the first man, and by the failure of the United States to follow through in support of the invasion of Cuba by U.S.-trained forces at the Bay of Pigs. In a memorandum dated April 20, 1961, President John F. Kennedy asked:

> *Do we have a chance of beating the Soviets by putting a laboratory in space, or by a trip around the moon or by a rocket to land on the moon, or by a rocket to go to the moon and back with a man? Is there any other space program which promises dramatic results in which we could win?*

What Kennedy hoped was to demonstrate to the world, through space achievements, that the United States remained the leading nation in technological and social vitality. Almost equally important, though not as clearly articulated, Kennedy saw such achievements as a means of restoring American pride and self-confidence. The Soviet Union's surprising demonstration of technological and strategic strength through its series of space firsts leading to Yuri Gagarin's flight had shaken our image of the United States as the unchallenged technological leader of the world.

After two weeks of assessing alternative answers to these questions, Kennedy's advisers, led by Vice-President Lyndon Johnson, agreed that the United States had at least a fifty-fifty chance of winning a competition to complete a successful manned lunar expedition and that no other alternative provided a better combination of achievement, risk, and cost. Kennedy accepted this assessment, and the Apollo program was born.

The memorandum to the President recommending the lunar landing effort was signed by Johnson, NASA Adminstrator James Webb, and Secretary of Defense Robert McNamara. It stated clearly the rationale underpinning the enterprise:

> *It is man, not merely machines, in space that captures the imagination of the world. All large-scale projects require the mobilization of resources on a national scale. They require the development and successful application of the most advanced technologies. Dramatic achievements in space therefore symbolize the technological power and organizing capacity of a nation. It is for reasons such as these that major achievements in space contribute to national prestige.*

Space achievements developed prestige, they asserted, in the power struggle between the United States and the Soviet Union; the United States should thus undertake a manned mission to the Moon, even if the scientific or military grounds were lacking:

> *Major successes, such as orbiting a man as the Soviets have just done, lend national prestige even though the scientific, commercial, or military value of the undertaking may by ordinary standards be marginal or economically unjustified. . . . Our attainments are a major element in the international competition between the Soviet system and our own. The non-military, non-commercial, non-scientific but "civilian" projects such as lunar and planetary exploration are, in this sense, part of the battle along the fluid front of the cold war.*

Kennedy accepted these arguments. In announcing this decision on May 25, 1961, he told the Congress and the nation:

> *If we are to win the battle that is going on around the world between friends and tyranny, if we are to win the battle for men's minds, the dramatic achievements in space which occurred in recent weeks should have made clear to us all, as did the Sputnik in 1957, the impact of this adventure on the minds of men everywhere who are attempting to make a determination of which road they should take. . . . We go into space because whatever mankind must undertake, free men must fully share.*

Apollo emerged from a crisis atmosphere, and stands as a powerful example of the fact that government can make and can keep a commitment to multibillion-dollar, long-term programs when they serve broad national purposes and are begun with adequate political support. The existence of a crisis situation made the Apollo commitment possible; it did not make it inevitable. Other circumstances had to converge to make Apollo happen. They include:

1. Enough prior research to assure decisionmakers that the proposed undertaking was technologically feasible; a manned lunar mission had been under serious examination for several years prior to the Kennedy decision, and no technological obstacles had been identified. NASA had selected a lunar landing as the appropriate long-term objective of its manned flight program over a year before May, 1961.
2. The undertaking was the subject of enough political debate that groups interested in it and opposed to it were identified and their positions and relative strengths were evaluated, and potential sources of support had time to develop. Both Lyndon Johnson and James Webb had effective working relationships with the leaders of Congress, and obtained pledges of support for an accelerated space program. The President and Vice-President also consulted non-governmental leaders to test their reaction to a vigorous U.S. response to the Soviet challenge in space.
3. In the political system, there were individuals in leadership positions whose personalities and visions supported the initiation of large-scale government activities aimed at long-term payoffs and who had the political skill to choose the situation in which such activities could begin with a good chance of success.

When Kennedy announced his decision to go to the Moon in May, 1961, there were no significant negative reactions, and the funds required to accelerate NASA's program passed Congress quickly and with little opposition. The program was well underway before such opposition first developed in 1963.

The Shuttle: a Bad Bargain?

Apollo, as a crisis decision, was an exception to how policy choices are usually made in the United States. The normal process of policy-making involves a wide variety of participants; it is characterized by bargaining among players positioned within various government organizations. Individuals and groups outside government participate in this process and can be very influential, but their power lies primarily in influencing those within the government who control the resources required to undertake a new course of action. Decisions are almost always made, not by one central decisionmaker, but by a process of interaction among various government organizations and individual political actors. The process leading to the 1972 decision to begin the space shuttle program is an example of the normal policy process in operation (Logsdon, 1979a,b).

In the shuttle decision, major participants were:

- NASA, both as an engineering organization eager to take on a new and challenging technology development job after Apollo and as a government agency interested in maintaining its budget, institutional base, and status;

- Department of Defense, attracted by the potentials of the proposed shuttle for various national security missions in space;

- the aerospace industry, interested in undertaking another major effort along the lines of Apollo;

- the Congress, still supportive of space but unwilling to approve another Apollo-like project aimed at, for example, manned planetary exploration;

- scientists skeptical of the value of or need for another major manned program to follow Apollo;

- analysts who, for the first time, examined a major space initiative in terms of its cost effectiveness;

- the Office of Management and Budget, protective of the budget and unconvinced that the shuttle was a good investment of public funds;

- the President's Science Advisor and his supporting staff and advisory committees, who believed that some sort of shuttle program was an appropriate post-Apollo space initiative, but who were skeptical of the NASA-defined shuttle as being the best approach to lowering the cost and increasing the ease of access to space;

- President Nixon and his policy advisers, skeptical of the future political payoffs from major space programs but unwilling to take the United States out of manned space flight and concerned about the employment impacts of programs such as the shuttle in key electoral areas like California.

The shuttle decision was the end product of a high-pressure, broadly-based, sometimes confusing debate that extended from early 1969 to early 1972, reaching a peak in the second half of 1971. The shuttle that President Nixon finally approved for development was dramatically different in both design and estimated cost from that which NASA had originally hoped to develop. NASA's planned shuttle had been part of a grand design for the post-Apollo space program aimed ultimately at a manned mission to Mars, with a space station and a lunar base as intermediate goals. The final shuttle design emerged from a process of negotiation, compromise, and conflict; it had the rationale, technical characteristics, and cost implications required to gain the support of the President and his advisers, the Department of Defense, and a majority of Congress, while still meeting most of the needs of NASA and its contractors. This coalition was able to overcome continuing opposition from the scientific community and the President's budget office, and thus provided enough support for the program to gain approval.

It was barely enough support, however, and the compromises made to make the decision politically acceptable made program success difficult to attain. NASA agreed to tightly constrained annual and total budget ceilings for the shuttle program, with little flexibility to accommodate technical problems that might arise. Some aspects of shuttle design may have been underexamined in the rush to make a decision, and NASA may have been overly optimistic in assessing the risks and technological readiness of various elements of the shuttle program, particularly the main engines and thermal protection system.

Further, what political support the program had (beyond NASA and its contractors) was not very intense. Only a few in the Department of Defense were involved in the decision process; the bulk of the Air Force was unenthusiastic. Presidential support was neither active nor strong, as had been the case with Apollo. Neither the President nor Congress had accepted, at the time of the decision, a vision of the nation's objectives in space that gave purpose and priority to the shuttle program. Not until the shuttle was threatened with cancellation in 1979 did the top leaders of the country decide it was critical to the verification of the proposed strategic arms limitation agreement (SALT II) and thus deserving of the support required to make it successful.

Selling the Space Station

NASA was forced in 1972 to accept a scaled-down shuttle program as all that it could "sell" to the nation, given the political context of the time. As shuttle development neared completion, the incoming NASA leadership in mid-1981 identified a permanently-manned space station as the agency's top choice for its post-shuttle program. Two and a half years later, after an intensive coalition-building effort, NASA was able to obtain approval to begin station development. Thus the decision to build the space station was another product of normal, non-crisis policy-making, but this time the President *was* active and supportive, and in the end that support proved decisive in allowing NASA to proceed with its top priority program (Waldrop, 1984).

Major participants in the space station decision were:

- NASA, needing another major development program to keep its technical capabilities fully occupied;

- the aerospace industry, hoping to continue to receive major NASA contracts but also beneficiaries of a major defense buildup;

- the Congress, which had been pushing for several years for a statement of long-range goals in space;

- the scientific community, determined to oppose any large new NASA program that would compete with space science missions for resources;

- the Office of Management and Budget, more convinced than ever that major manned space programs were an unneeded drain on the federal budget;

- the Department of Defense and other elements of the national security community, which opposed the space station both because it was not essential to any military need and because it might compete with higher priority DOD programs for funding;

- an emerging community of potential space station users and organizations committed to developing commercial applications of space technology;

- President Reagan and his policy advisers, who saw space leadership as important both symbolically and economically and who accepted NASA's argument that the space station was the logical next step in maintaining that leadership.

NASA had been studying various types of space stations for two decades prior to 1981; these study efforts were coalesced into an agency-wide task force in May, 1982. This task force identified mission requirements, assessed technological requirements, and defined a space station architecture; thus various technological uncertainties were being reduced as the decision process proceeded. NASA also asked the National Academies of Sciences and Engineering to assess the station's potential.

Thus when the station decision came before the President, the technical, policy, and budgetary aspects of the undertaking had been fully articulated, and all interested parties had had an opportunity to make their views known. The President could apply his judgment in order to resolve the conflicts between NASA's proposal and the views of other agencies. He did so in a way that linked the space station to broad national objectives such as national pride, international leadership, and economic growth. Even in the face of growing budget deficits, Ronald Reagan was willing to use his Presidential prestige in support of the space station.

Whether such strong Presidential support has created a political base for the station program solid enough to withstand criticisms and attacks is yet to be seen, although the first year budget for the station program was approved essentially unchanged. Just as it had taken several years to develop the support that led to a Presidential go-ahead in January, 1984, it may take several years to assess the lasting power of that support.

Some Observations

Perhaps the most basic comment to be made regarding these brief case studies is that they demonstrate how a major space commitment can emerge from three very different situations. Of the ingredients for program approval (at least in a form facilitating program success), only one appears essential: strong support from the President. It is basically impossible to begin and complete a large-scale, long-term government program without a lasting bankable commitment from the White House.

The word "bankable" is important here. While it is conceivable that President Reagan, acting upon the recommendations of the National Commission on Space, could announce before 1989 a commitment in principle to a long-range plan for space exploration that includes establishing a lunar base, that commitment would have limited significance until it is translated into the resources required to implement the program.

The fact that there was approximately a decade between the Apollo and shuttle and between the shuttle and station commitments suggests that the President and the rest of the policy system are likely to be willing to provide substantial funding for only one major manned space project at any particular time. While the priority assigned to the multi-billion dollar space program among various government programs has been both high and low, it is hard to imagine the President ever according the civilian space program enough priority to accommodate two or more simultaneous large development efforts. If this conclusion is valid, then lunar base advocates are likely to have to wait until the 1992–1995 period, when station funding and personnel requirements decrease and when the success of the station program is evident, before they have much hope of receiving the kind of Presidential support that commits substantial resources to their favored program.

An earlier Presidential commitment in principle to a lunar base program would, of course, significantly increase the odds of a second, more meaningful commitment later. But it does not guarantee such a commitment. Decisions to begin a large-scale program are very much a product of the favorable convergence, at a particular time, of a number of factors, including:

- the specific political context;
- the visions, values, and styles of individuals in key leadership positions, particularly the President;
- the ambitions and needs of the organization that would carry out a proposed program, particularly as interpreted by the leaders of that organization;
- the ambitions and needs of other organizations that view themselves in competition for the same share of limited national resources required to carry out the program under consideration;

- the outcome of earlier programs of the same character; program success not only in technical terms but also in political terms is essential to approval of any "logical next step;"

- the program choices available, their technical, budgetary, and political characteristics, and their potential payoffs.

The preceding historical review suggests how the interplay among these factors in 1961, 1969–72, and 1981–84 led to decisions to allocate substantial resources to major new undertakings in space. In retrospect, it is clear that many of the factors that made those decisions possible were well beyond the control of those advocating a major new start in space, and so it is likely to be at the time when a lunar base proposal appears on the White House and Congressional agendas.

To say that advocates of a lunar base (or any other large scale program requiring government funding) cannot control the policy process determining the program's fate is not to say that they have no influence on policy-making. There are two general categories of actions that can have such influence: (1) providing a sound technical basis for decision-makers; and (2) developing and honing a convincing program rationale and attempting to broaden the base of those who accept that rationale and are willing to advocate it.

Effective studies and preliminary research and development activities can combine both "technical" and "advocacy" components. A major role of conceptual studies and exploratory research is to reduce technical uncertainties about the character and consequences of proposed courses of action. All participants in policy-making want to understand the payoffs, the cost, and the risks associated with proposed actions, and technical studies can reduce uncertainties about such outcomes. Studies can cast light on the technical, economic, organizational, legal, and perhaps even the political consequences of a particular program, and thereby help policy-makers understand the stakes involved in their actions.

Another way technical studies can make a general contribution to policy choice is by providing the basis for an extremely persuasive argument in support of a particular course of action. If one participant in policy-making has an articulate case in support of his point of view (note that this is different from having an objectively conclusive analysis), he has a powerful asset in the policy-making process. Policy-making is not only a competition among powerful groups; some ideas and concepts also confer power on those who put them forward. In making policy in technology-intensive areas, arguments cloaked in the garb of technical analysis have particular potency.

These comments are intended to suggest an agenda for those who are convinced that a lunar base program is in the national, indeed the world's, interest. While they wait with, hopefully, controlled impatience for the time, some years in the future, when a Presidential go-ahead on such a program is at least potentially attainable, program advocates should be attempting to convince those who control the relevant year-by-year budgets to provide enough support to carry out the studies and exploratory research needed to reduce those unknowns that can be explored without a major investment of resources. They should use their technical work as the basis for building a case for a lunar base that, for the time being, does not claim more than can be demonstrated rather conclusively, i.e., their advocacy should not outrun their data. They should continue to communicate their ideas to a broader audience, but not attempt to mobilize broad-scale support until it can count in policy-making.

This is a recommendation for moderation in advocacy, and is not likely to be palatable to those who want to move ahead as quickly as possible. It derives from several decades of careful observation of how the policy process works. As long as government funding continues to be absolutely required for enterprises like the lunar base, then persons interested in seeing those enterprises come into being must accept the reality of government decision-making. Wishing away the normal policy process won't work, at least in the absence of some significant action-forcing stimulus—a crisis.

In describing the decision to go to the Moon, I suggested that "the politics of the moment had become linked to the dreams of centuries and the aspirations of the nation" (Logsdon, 1970, p. 130). There is no way to *make* this happen, but it seems to be the necessary condition for making the dream of a permanent lunar base become a reality.

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THE BUDGETARY FEASIBILITY OF A LUNAR BASE

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At a time when there is almost constant concern and discussion about fiscal deficits and the need for budgetary stringency, the financial feasibility of a lunar base is certainly a legitimate issue. Conservative cost estimates have indicated that a permanent lunar facility with significant scientific and/or industrial capability can be established over twenty years for well under $100 billion in current dollars. The Apollo project was carried out in half that time, for a cost of approximately $80 billion in current dollars, during a period when the actual GNP was only half of what it is today. Projecting the GNP to the end of this century and assuming historically consistent outlays on space activities, we conclude that a lunar base program can be carried out in an evolving space program without extraordinary commitments such as occurred in 1961.

The establishment of a permanent lunar base will require large sums of money over long periods of time, and this program is under discussion at a time when there is great concern over the size of the federal deficit. The question addressed here is whether a program of this sort is affordable at the present time. The conclusion is that, in fact, a permanent lunar base can be financed without increasing NASA's historical budgetary allocation.

In our analysis, it is assumed that the basic costs of space infrastructure will have to be borne by the federal government, and what part private sector funding might contribute to this project is not considered. Eventually, however, there may well be opportunities for corporate activities in space that lessen the pressure on the public sector for the finance of the space program. Neither have we taken into account the possibility of other nations participating in a return to the Moon and sharing the costs. This certainly would be desirable, but we suspect that even if there should be other participants in the program, the major burden of the cost would be borne by the United States.

A NASA/Johnson Space Center team (Roberts, 1984) has made various estimates of the cost of a lunar base. That team studied three separate scenarios with distinct emphasis on resource utilization, colonization, or science. In each case, a space transportation system capable of delivering payloads to lunar orbit was assumed to exist in the latter part of this century. Transportation elements developed specifically for the exploration of the Moon and for establishment of the base were charged to the program. Other cost items included surface facilities and transportation costs such as fuel and operations expense. The derived costs range from a low of $79 billion for a program with an emphasis on utilizing lunar resources to a high of $90 billion for one with an

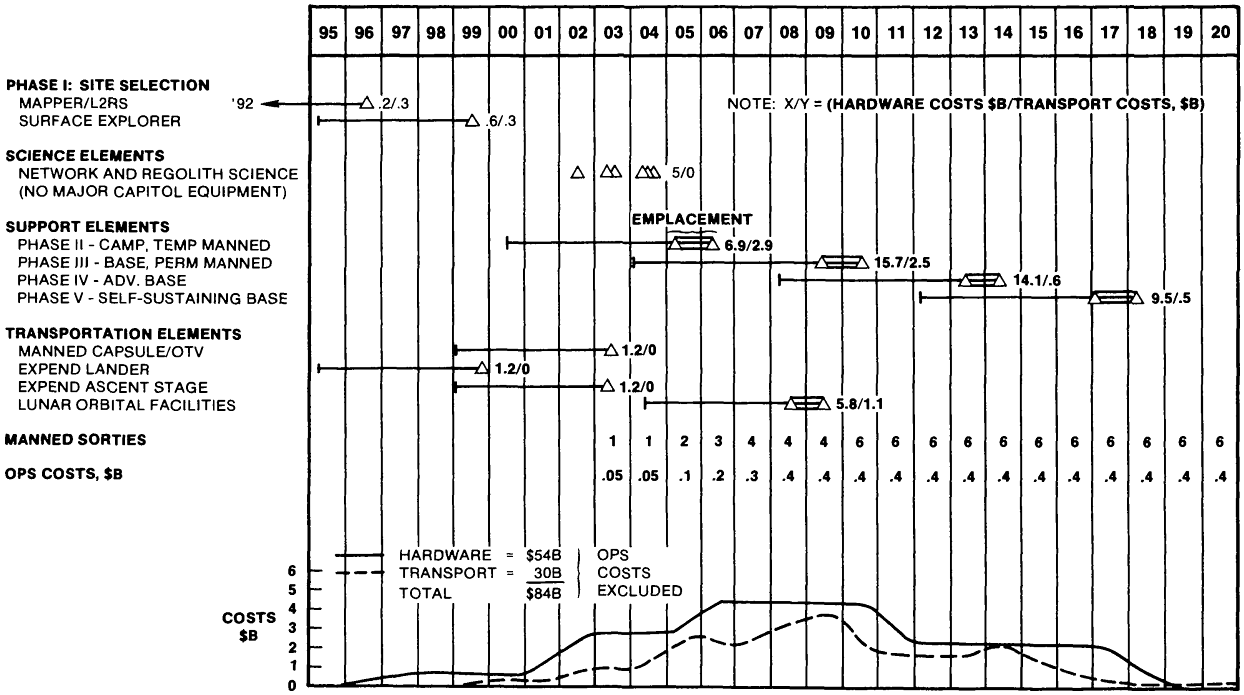
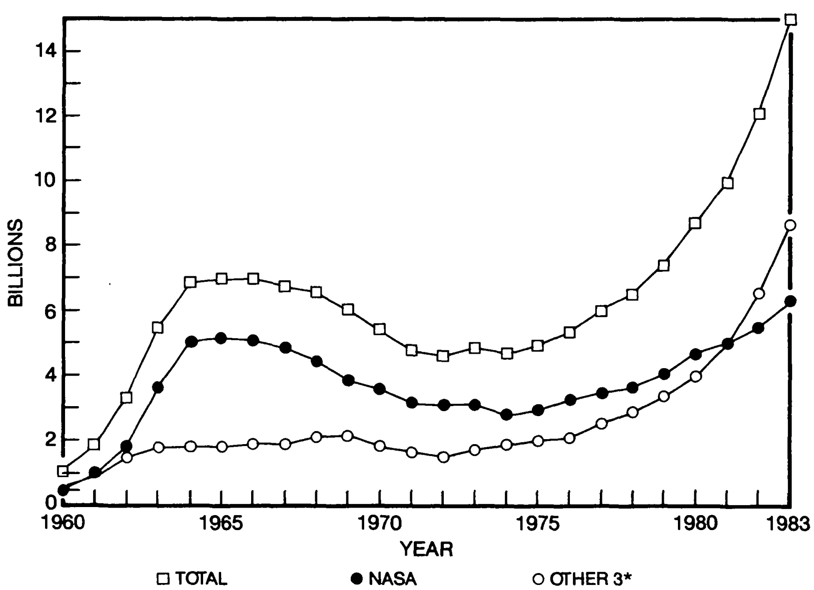


Figure 1. Cost estimates of lunar base colonization.

emphasis on self-sufficiency and colonization. Figure 1 shows the most expensive scenario. To be conservative, we can say that with the establishment of a proper transportation system, it will cost under $100 billion over 25 years to put a base on the Moon. For comparison purposes, the Apollo costs to place man on the Moon were about $80 billion over eleven years. All of these costs are quoted in 1984 dollars.



*Other three include Dept. of Defense, Dept. of Commerce, and Dept. of Energy.

Figure 2. Dollars authorized by the Federal Government for ●-NASA, ○-Departments of Defense, Commerce, and Energy, and □-the total federal outlay.

Timing of expenditures is almost as important as totals in a program of this sort. The NASA team estimated maximum yearly expenditures for hardware and transport to be on the order of $6–9 billion in 1984 dollars, depending upon the activity emphasized by the base. The period of 2006–2010 or even later would require the heaviest annual funding as a percentage of federal outlays.

Figure 2 shows dollars authorized by the federal government for the space program, and Fig. 3 shows total expenditures for the space program, and the NASA budget as a percentage of federal outlays.

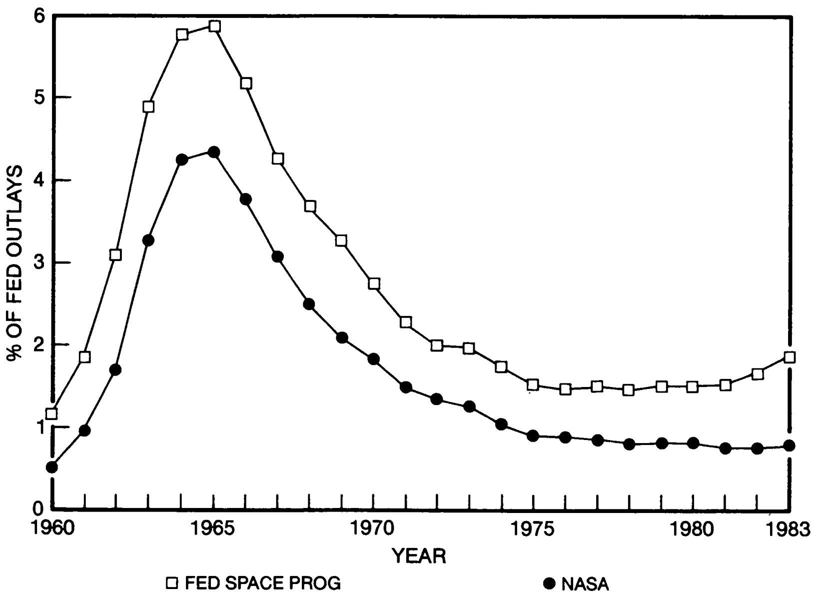


Figure 3. Percent of federal outlays for o*-the total space program and* ●*-the NASA budget.*

An examination of the relationship between total federal government outlays, total expenditures for the space program, and the NASA budget shows that our nation's largest space effort was made during the 1960s when we made a determined national commitment to place a man on the Moon (Fig. 2). This effort was initiated by President Kennedy but remained a real national goal under succeeding administrations with full support from the Congress. During this period, total outlays for the space program rose to almost 6% of federal outlays, and the NASA budget was over 4½% of federal outlays. Looking back to this 1960s period, we see how extraordinary this effort was. It required the spur to national pride of Sputnik's success, the full commitment of an eloquent President, and a period of relative prosperity to bring forth this sort of effort.

During the early 1970s, we had a steady decline in the share of federal outlays dedicated to NASA and the total space program. By 1975, expenditures for the overall space effort leveled out at about 1½% of Federal outlays, and they have leveled out at 0.8% of federal outlays since 1978. The stability of NASA's share of outlays in recent years would seem to indicate that there is a base of support in Congress for at least this level of expenditure, reflecting the fact that American public opinion toward the nation's space program is more favorable than at any time in our history. For our projections, we assume that

Table 1. Federal Outlays in Relation to Gross National Product

Year	GNP Calendar Year (billions)	Outlays Fiscal Year (billions)	Outlays as % of GNP
1960	$ 507	$ 92.2	18%
1965	691	118.4	17%
1970	993	195.7	19%
1975	1,549	324.2	20%
1980	2,632	576.7	21%
1985	3,951*	925.4	23%

*1985 Merrill Lynch Estimates

NASA will be accorded at least 0.8% of federal outlays as its share in the next 35 years, the period over which a permanent lunar base could be established.

The next problem is to determine the likely size of federal outlays in the period 1995 to 2020, a difficult problem, especially in view of present efforts to reduce the federal budget.

The federal outlay percentage of GNP has increased from 18% in 1960 to 23% in 1985 (Table 1). It seems unrealistic to expect that outlays will be reduced to the 17–19% level of the 1960s because of the many new domestic programs that have been added, the increasing use of indexation, and the higher level of defense spending. We use an estimate of 20% as a base case for federal outlays as a percentage of GNP, although we also show the figures for federal outlays at 22½% of GNP.

The U.S. GNP over the relevant time period remains to be estimated. Economic forecasting of GNP for a specific year in the future has not developed a particularly positive image in recent years. On the other hand, over the very long run, growth in GNP in the U.S. has been quite consistent. If one looks at the historical record over the past 100 years (Table 2), the GNP has shown a compound growth rate of slightly over 3%. In the 1960–82 period, the compound rate of growth of real GNP has been 3.6%, although

Table 2. Growth Rate of Gross National Product in the United States

Initial Year	Terminal Year	Growth Rate
1874*	1970	3.6%
1884*	1970	3.3%
1890	1970	3.3%
1900	1970	3.2%
1910	1970	3.0%
1920	1970	3.3%
1930	1970	3.5%
1940	1970	3.9%
1950	1970	3.6%
1960	1970	4.0%

*Average for decade

Table 3. Available Funding

GNP Growth	3%		3¼%		3½%	
Federal Outlays as % of GNP	20%	22½%	20%	22½%	20%	22½%
Available to NASA at 80% of Federal Outlays 1995–2010 ($ Billions)	$306	$344	$325	$366	$346	$389

the range for individual years went from a high of 10.8% from 1971–1972, to a low of −1.9% from 1981–1982 (U.S. Bureau of Census, 1983). Some idea of the consistency of the growth rate of Gross National Product in the United States (U.S. Bureau of Economic Analysis, 1973) can be seen in Table 2.

These projections estimate growth in GNP at 3%, fractionally below the history of the last 100 years. Fiscal 1984 GNP is estimated at $3,581 billion, an average of the fourth quarter of 1983 and the first three quarters of 1984.

Table 3 shows the monies available for NASA, assuming this 3% GNP growth, plus federal outlays at 20% (below the experience of recent years but high historically), and a NASA budget of 0.8% of federal outlays, the lowest level since 1961. In spite of these relatively conservative assumptions, the anticipated budgetary allocation to NASA of over $300 billion will exceed the full cost of a lunar base by more than threefold. Budgetary constraints should not be a significant hurdle to a permanent lunar base. To put it quite simply, if we want it, we can afford it.

Table 3 also includes what might be available to NASA assuming somewhat higher growth rates in GNP and somewhat higher federal outlays. It demonstrates the obvious: the higher the growth in GNP, the more easily programs can be financed.

The present problem of the federal budget deficit amounts to about 22% of all federal outlays. We expect that this problem will be addressed by a modification of the entitlement program, defense spending, tax revenue rates, or growth in the economy, and most likely all four. We certainly do not expect that the 22% deficit problem would be addressed by, for example, cutting NASA's share of federal outlays to 0.4% from 0.8%. Even if that were done, NASA could still afford to adopt a lunar base as a primary long range goal providing no other major civilian space initiatives were made.

One factor that should be kept in mind is that the commercial benefits that will be derived from space over the long run are likely to be substantial. The two key contributions to be made by the federal government are (1) a reduction in space transportation costs and (2) simply providing experience for human activities in space. With assistance from the government in these two areas over the next decade or so, it is likely that commercial exploration of space will lead to substantial financial benefits for the private sector and, eventually, for the public sector.

The decision to go forward with a lunar base program is quite obviously a political decision that is uniquely difficult because the program is such a very long one that cannot be funded in fits and starts. It is essential to understand that subject to the appropriation process of Congress and the performance evaluation of the Executive branch, these expenditures would continue into the next century. Once initiated, we are truly committed.

The commitment should be made now; in the long run, it is probably inevitable. The sooner it is made, the more intelligently and economically the lunar base can be planned and implemented. We believe that the program is affordable.

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LUNAR STATIONS: PROSPECTS FOR INTERNATIONAL COOPERATION*

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In the 1960s, two years before the first Apollo landing, it was my good fortune to take the leaders of the nation's space program to Antarctica. Bob Gilruth, Wernher von Braun, Max Faget, Ernst Stuhlinger, several of the Apollo astronauts, and others participated. The purpose was to look at all dimensions of the Antarctic program—the scientific program and its planning, the logistics necessary for its support, search and rescue procedures, the effects of long stay-times in isolation and other human factors, and international cooperation among the nations working on that continent. These space leaders felt Antarctica was the best Earth model in actual operation on a scale of projected space activity from which to draw ideas about space stations, and particularly lunar station planning. That expedition stimulated my own interest in lunar stations, one that has continued to this day. Thus, when offered the opportunity to attend and participate in this conference, I immediately responded in the affirmative.

My subject is the prospect for international cooperation in lunar station planning. In considering policies for a U.S. program, and as other nations consider their policies for future lunar station planning, it is inevitable that international cooperation will be a dimension carefully reviewed and discussed. Without commenting as an advocate or a critic on the desirability of a lunar station or a series of them, the time of their construction, or the desirability of international cooperation, it is possible to project several modes of scientific, logistics, private-public sector, and other cooperation that could take place on the Moon. My objective is to lay out a few ideas concerning different modes of cooperation in the hope that these thoughts will contribute to and perhaps stimulate some of the discussion over the next few years.

ASSUMPTIONS

I begin by stating that my crystal ball gets quite cloudy beyond the first three decades of the 21st century, so my remarks are really focused on the next fifty years. My further planning assumptions are five in number.

First, a return to the Moon for extended stay-times will take place within the next fifty years.

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* Views of the author, not those of the National Academy of Sciences or the National Research Council.

Second, at this point in the discussion of future lunar station activity, it is unwise to advocate any one model of national or international activity. Nations should understand various modes of cooperation, but, as nations, should keep options open until renewed lunar activity comes into clearer view.

Third, while transnational enterprise is a worthy goal, national enterprise, that is, the activity of nation-states, will continue to be the important and dominant factor in the development of space for quite some time to come. The first three decades of space have been dominated by national objectives although limited private sector economic cooperation has begun. National activity will probably be the continuing condition in the decades ahead. On the other hand, dominance of space activity by national enterprise has not ruled out international cooperation in space missions, nor would it in lunar base development.

Fourth, in early years of extended stay-time on the Moon, the principal rationale will be scientific observation and the logistic support of those observations by humans or automated facilities. Another early thrust may be the use of the Moon as a logistic or resource platform for other space activities. True lunar industrialization or commercial activity in the economic sense, at least in my view, lies somewhere beyond the next fifty-year period. Thus it is somewhat beyond the framework of my discussion. If for some reason economic or commercial development becomes attractive at an earlier point in time, it will inevitably change the character of international cooperation that may ensue.

Fifth, I assume that the Moon will not become a military platform and will remain a body of peaceful enterprise where a nation's national security interest is maintained and expressed through ability to participate in scientific and other lunar ventures.

NATIONAL ENTERPRISE

The exploration of the Earth over the last several centuries has been dominated by nationalism—the mounting of national exploratory expeditions, generally nationalistic and oftentimes economic in purpose. The national enterprise has been centered in exploration of new territory, its settlement, and its potential economic exploitation. This, of course, is the obvious fact of history. However, it is interesting to recall that in this framework of nationalistic activity there has long been an associated observational or scientific activity. And increasingly in this century, scientific cooperation has been a principal means of maintaining national visibility and has been accepted as a premise in international relations and in development of some international law.

In the 1800s some of the great national enterprise expeditions were essentially geographical and scientific. The Lewis and Clark expedition was an exploring and scientific expedition, sent out under the auspices of a President and Congress. In the late 1700s and early 1800s, Great Britain, the United States, France, and Russia all mounted major Pacific Ocean and Southern Ocean exploratory expeditions. In their day they were akin to a lunar or martian expedition: one left with the expectation of being away from home for several years, possibly not returning at all.

A number of national polar expeditions were mounted in 1898 as a part of an International Polar Year. A second Polar Year occurred in the early 1930s, again with nations contributing their scientific observations to a shared good. But at the same time, in Antarctica especially, these national enterprises furthered national objectives. The first expeditions of the late Admiral Richard Byrd took place in that period. In Antarctica, in fact in this century, there was a period of fifty years of relatively intense nationalism, in exploration and science, before the new period of international activity that was ushered in by the International Geophysical Year.

The Antarctic Treaty that has governed that continent's research and other activities was signed in 1959. It became a model, or at least a vision, of the way space activity could proceed. The Antarctic Treaty resolved or set aside some vexing legal issues, but activity there has continued primarily as national activity. It is interesting to note that national pride, expressed through the fulfillment of scientific objectives, continues to play an evolutionary role in Antarctica. There are a number of new entrants into Antarctic activity—West Germany and more recently India and Brazil. Within the last few weeks, the People's Republic of China has announced that it will send an expedition of some 500 individuals, counting those individuals on board two ships, to Antarctica for a 1984-1985 summer expedition, a forerunner of a year-round station established for the purpose of undertaking scientific research, but also fulfilling national objectives comparable to the activities of other large nations working in Antarctica.

Today it may be easier in the United States for us to think about international activity on the Moon than it is in some other nations, because we have already been there. We were the first to arrive and plant a flag, a source of pride for all people, but a special source of joy for Americans. There may be, among some Americans, a more generous attitude concerning international cooperation than may exist in other nations. We should remind ourselves of our own history to appreciate how others may see us in relation to their own national enterprise objectives in space. During the exploration of the American West, the spirit of "manifest destiny" was rampant. It was a time in which one would have heard little about international cooperation for any frontier enterprise whatsoever—scientific or otherwise. Thus it is conceivable that other nations may wish to achieve their own "manifest destiny" through expeditions to the Moon.

In our time, since the great success of the International Geophysical Year, there have been many international cooperative ventures in science. They provide concepts of several ways we might proceed on the Moon. In science, aspirations for international cooperation, peaceful development, and common purpose have now become one of the cardinal features in a century that is truly the century of science. The vision of space and of the Moon as an opportunity for a successful new international or transglobal beginning is attractive. However, if history is any guide, perhaps we should think of an evolution that progresses toward that point out of continued national enterprise.

Thus, I suggest, as one projects ahead to the end of the 20th century and early into the 21st century, that national enterprise might play a very large role in lunar activity. The United States, the Soviet Union, and other major players in the space arena will undoubtedly continue to express national pride by way of national scientific and technological prowess in space. Japan, a nation striving very hard to be totally competitive with the United States and other industrial powers, could well find its own national interest served in a manned expedition to the Moon.

INTERNATIONAL ACTIVITY IN THE CONTEXT OF NATIONAL ENTERPRISE

What are the implications for cooperation in lunar activity if national enterprise continues to be a strong and dominant feature of space exploration? There are a number of possible scenarios.

It would be possible for the United States to define and finance most of its own plans for lunar station activity but to offer participation to other nations and to their scientists. This form of international cooperation would be somewhat along the lines of the arrangements worked out for the development of the space lab by the European Space Organization.

There are a number of Earth models of this kind of cooperation. The International Program of Ocean Drilling, a highly successful program in which five countries participated, was in its initial years the Deep Sea Drilling Project of the United States, funded through the National Science Foundation. The program had an interesting evolution. After its initial eight years as a U.S. enterprise, but with scientists from other nations involved, the United States extended fuller membership in financing and planning to the U.S.S.R., Federal Republic of Germany, Japan, France, and the United Kingdom. Budgetary pressure forced the international phase of ocean drilling beginning in 1975. After political developments surrounding the Soviet entry into Afghanistan in 1979, that country withdrew. We or another nation could proceed with lunar development along the lines of this model. The lunar settlement for scientific work could be initiated with some guest scientists and eventually fuller operational partnership offered to other nations.

There is another scenario. If other nations are only partly convinced to work within the program of a dominant space power such as the United States because of their own desires to prove fuller partners or competitors, it is conceivable that there could be more than one national expedition to the Moon by the early part of the next century. There could in fact be independent expeditions by several nations. In such a case, it would be possible to construct a framework for international cooperation such as those established through the International Council of Scientific Unions. By common agreement through ICSU, observations in space from the Earth or unmanned space platforms, cooperation in the atmospheric sciences, oceanography, glaciology, and other disciplines was established in the IGY and has proceeded since. The Committee on Space Research (COSPAR) has played this planning role in space science. There are a number of major activities in Antarctica that go forward this way planned under SCAR, the Scientific Committee on Antarctic Research. The International Antarctic Glaciological Project, for example, in which France, the Soviet Union, the United States, Australia, and Great Britain have participated, is a decadal survey of the East Antarctic ice sheet. The project was planned and is being coordinated through SCAR. Independent national activity coordinated through an ICSU-like arrangement would in itself be a successful method of international cooperation on the lunar surface.

A variation on this model is a cooperative mode buttressed by both an international planning organization and a non-governmental international scientific union. In the highly successful Global Atmospheric Research Program (GARP), individual nations pool their scientific and logistic efforts. GARP is planned scientifically through ICSU and nationally and logistically through the member states of the World Meteorological Organization (WMO). While WMO is under the overall aegis of the United Nations, I do not stress that aspect. Indeed, the fact that the WMO has been uncharacteristically free of the political agenda of the developing nations is the ingredient that has made the WMO-ICSU arrangement for GARP successful. For over a decade, a series of observational programs culminating in the Global Weather Experiment has been carried out. One could imagine the formation of a specialized international governmental organization like WMO and an ICSU scientific union that would together coordinate a lunar observational program of several decades duration where national expeditions of varying length, unmanned observations, and permanent stations on the Moon could be established. The participating nations would budget and mount their own lunar efforts, but under these newly established international organizations. Their efforts would be coordinated to achieve more effective strategies than would be obtained by uncoordinated effort.

Another direction lunar cooperation might take would be the development of bilateral arrangements between two countries electing to pool their resources. In the post-World War II period there have been many bilateral agreements for cooperation in research. Many are negotiated at the level of heads of government. Many are at an agency level; some are arranged by other organizations within nations. Bilateral agreements arranged at the level of heads of government have often been very stable over successions of governmental leadership. Most of these bilateral agreements have been prompted by a combination of scientific or technical interests and political objectives that could be served by cooperation. As one surveys programs of the industrialized nations in research and development today, one finds an increasing effort to utilize bilateral activities for the conduct of expensive longer term research programs. For example, there are international bilateral activities to promote fusion research.

The most famous bilateral activity in space, of course, is the Apollo-Soyuz linkup a decade ago. If, by the turn of the century, the United States and the Soviet Union remain the principal spacefaring nations they could decide to pool resources. With impoverished communications between the nations it is hard to think about it, but one could imagine the United States and Soviet Union arranging—several decades from now—a bilateral agreement for a joint lunar effort. In this case there would develop a lunar program that was cost-shared and planned according to agreed-upon principles of joint funding and management. The two countries, as principal partners, could extend cooperation to other nations.

It is also conceivable that two or three nations could team up in a bilateral or trilateral effort to pool their energies to match or parallel a strong unilateral effort of the United States. For example, the emerging industrial Pacific Rim high technology nations such as Japan, the People's Republic of China, Korea, and others could among them create a bilateral or trilateral effort for lunar activity.

TRANSNATIONALISM

There has been much discussion about transnationalism in which there would be, in effect, total international cooperation amongst a consortium of nations and their scientific and engineering communities for the planning of lunar stations. Transnationalism seems to work better in theory than in practice. Nonetheless, if one looks at Western European cooperation today, as compared to European cooperation of two to three decades ago, there is much evidence of growing transnationalism in scientific and economic enterprise. One must conclude that true transnationalism in lunar base planning is a possibility, even though I have suggested earlier that I believe it will be slower in developing on the Moon than some other modes of cooperation. A discussion of the economic and political conditions necessary for true transnational cooperation in lunar station development would require a separate, extended discussion. But what if there were a real sea change in the affairs of nations? Transnationalism in lunar scientific or observational cooperation could be possible.

As a model, there is the highly successful transnational enterprise in high energy particle physics. The European Laboratory for Particle Physics—its French acronym is CERN (Council of Europe for Research Nuclear)—was organized in the early 1950s and started with eleven member nations that pooled their resources for the construction of the several accelerators located at the edge of Lake Geneva. Thirteen nations now contribute. Collectively, CERN nations compete with the U.S. program in high energy physics and those of other nations. The United States helped organize CERN and contributes as a limited partner to its costs through the Department of Energy. U.S. scientists are CERN experimenters. There have been many problems over the years. Today, for example, Great Britain is suggesting that it may withdraw. These difficulties have been resolved successfully for two decades. CERN is a truly representative model of a kind of transnational science activity that could go forward on the Moon.

PRIVATE SECTOR ENTERPRISE

To complete this survey of prospective modes of international cooperation, let me mention still another possibility, although it may presume more actual economic potential in lunar exploration in the next fifty or so years than could take place. This would be the development of a non-nation state international consortium of private interests that would, in fact, plan lunar station activities.

The International Telecommunications Satellite Consortium (INTELSAT) is such a model. On Earth, there are many energy, mining, and construction consortia that are of a similar character. Were such a lunar venture to emerge, one might suspect, however, that national interests of the several nations interested in lunar and space exploration might come into play in a regulatory sense or because of other considerations. These discussions seem to arise for several reasons, including the need for continued and substantial subsidization of the private enterprise by public funds and the national interests that must be protected. So, one could anticipate that if a non-nation state consortium for international cooperation on the Moon were to develop, it might be heavily regulated by the several governments of the venturing partners. Or, the consortium could get swept up in north-south political questions through the United Nations unless the newly industrializing nations have by the early part of the next century sufficient economic self-interests in lunar efforts that this model would appeal.

Unlike Antarctica, where exploration of mineral resources and hydrocarbons is still seen as economically distant after 160 years of exploration, an extractive resource industry on the Moon may certainly develop comparatively early in the history of lunar occupancy. The extractive resource activity could well be operated by commercial, private sector companies. These companies, within the time frame of my assumptions, would doubtless be under contract to a government or governments.

A more likely variant involving commercial or private economic interests could be the utilization, by nations, of private sector enterprises to operate lunar research facilities. Again, there are successful models to be examined. Consortia of universities in the United States operate astronomy observatories for the National Science Foundation. Since World War II, the Energy Department and its predecessor agencies have operated, under service contract agreement with companies, facilities such as the Oak Ridge National Laboratory. NASA has contracted with companies for the operation of its facilities. In the lunar case, such service and support ventures could be international in scope but private sector enterprises.

CONCLUSIONS

I have not stressed truly transglobal enterprise on the Moon, an international effort by all nations on the Earth carried out under the United Nations or some subsidiary. It would, on the basis of past experience, require a collective spirit of enterprise that is difficult to imagine in the fifty-year time span I have been addressing. At every level of human endeavor such transglobal enterprises run into barriers. Even mountain climbers who have attempted multinational assaults on Mount Everest and other mountains have had mixed success. The scaling up from that comparatively simple level of effort to any other presents insurmountable difficulty today because of the debate between the industrialized and the developing nations. Perhaps it will be different by 2020.

In the absence of a transglobal United Nations-like effort, there are a variety of ways in which international cooperation in lunar station planning might proceed. There may be no preferred strategy, nor a model from past or current experience that will apply early in the next century. A range of opportunities for cooperation will exist for the United States and other nations. National and international interests will have to be balanced and weighed. Since scientific cooperation may offer the only early rationale for extended lunar activity, the traditions of international cooperation in science forged in our time will certainly be examined and re-examined by nations planning lunar stations some decades from now. Indeed, our successes in international scientific cooperation are a great legacy to give to those who will plan the return to the Moon.

SOVIET LUNAR EXPLORATION: PAST AND FUTURE

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After a hiatus of more than a decade, Soviet lunar exploration is now expected to resume in 1989 with the launch of an unmanned polar orbiting survey probe. Now is thus a good point to take stock of Soviet space capabilities applicable to advanced lunar missions and to make estimates of future options based on these capabilities. To do this, a brief but full chronicle of past Soviet lunar exploration is required.

The successful launching of Luna-1 on January 2, 1959—the first space probe to escape from Earth—had been preceded by at least three launch failures starting the previous September (according to recently released government documents at the LBJ Presidential Library in Texas). It was followed by another failure in June and then two successes in the fall, a lunar impact and a lunar farside photographic fly-by. Two additional farside photographic missions the following spring failed. So of the first series of Soviet lunar probes, there were three successes in nine attempts, a success rate not unlike that of the early U.S. Pioneer program.

Beginning in January 1963, Soviet hard-landing spacecraft were launched toward the Moon. Success was finally achieved with the Soviet Luna-9, four years and several failures later. This feat was followed within months by the five (of seven attempted) NASA Surveyor soft landings; one later Soviet hard-lander, Luna-13, was also successful.

The distinction between "soft-lander" (<1 m/s touchdown speed) and "hard-lander" (5-10 m/s touchdown) has generally been forgotten, since the only American hard-lander program was the unsuccessful early Ranger/Block II series in 1962. Surveyor, Viking, and the Apollo lunar module were all soft-landers, as were the large Soviet Luna vehicles of 1970-1976. The early Soviet hard-lander probes (1963-1966) relied on collapsible structure that allowed their high-shock-resistant electronics to survive. Such a design is simpler to build but severely restricts the range of research apparatus capable of being carried safely to the surface.

The characteristic string of flight failures that almost always inaugurated the appearance of every new class of Soviet deep space probes should be interpreted less as evidence for engineering incompetence than as the result of a conscious—and not at all unreasonable—development philosophy. Soviet space engineers evidently concluded that it could be cheaper to perform shakedown flights in orbit than to undergo a long series of expensive ground tests and computer analyses; American space engineers were unwilling to face the political costs of a deliberate approach that almost guaranteed a string of publicized and embarrassing failures. Soviet spacecraft were thus committed to flight earlier in their development than corresponding American vehicles, but they would take a longer flight program to fully mature.

In the summer of 1966, three Soviet probes were successfully put into lunar orbit for science and photographic surveys. At least one of the payloads failed without sending any data.

MAN-TO-THE-MOON RACE

A separate Soviet lunar program eventually appeared under the cover name "Zond" (or "probe"), which had earlier been used for a series of interplanetary missions. This lunar Zond series involved the launching of modified "Soyuz" man-rated spacecraft on a translunar loop and its return to Earth. The first attempts were made early in 1967, with a successful mission coming eighteen months and four or five failures later. (Reportedly, one capsule came back far off course and was recovered by the Chinese, who for many years exhibited it in the Red Army Museum in Beijing.)

The Zond program was evidently part of the secret Soviet man-to-the-Moon race, in competition with Apollo. But American astronauts orbited the Moon first (in December, 1968) and seven months later were walking on its surface.

If there is one major disappointment in the way in which Apollo has passed into our history books, it is related to the purpose of John Kennedy's original 1961 vision. He wanted the project to demonstrate American technological superiority to the world, and particularly to the Soviet Union. At the time of his famous speech, the world believed that the United States was years behind in the "Space Race". Hindsight shows the Soviets were orchestrating "space spectaculars" with little more than a year's head start on a moderately bigger booster rocket, but at the time it seemed to require a miracle for the U.S. to catch up.

Unfortunately, when the miracle was ultimately delivered, the heart and soul of it—the victory in the Moon Race—was torn out of it by a clever Soviet propaganda ploy. In a special Apollo 11 fifth anniversary program in 1974, Walter Cronkite summed up the consensus of his media colleagues (but NOT of the experts) that there had never been a Moon Race after all.

Recent contributions have been made to the mountain of evidence showing that the Soviets in the 1960s were trying their utmost to build spacecraft and boosters to fly cosmonauts around the Moon and, ultimately, to land them on the surface. This new evidence includes testimony of Soviet emigrants as well as uncoordinated public statements by official Soviet spokesmen who have disclosed some revealing new details.

In the early 1980s, amid worldwide concern over falling Soviet satellites with nuclear reactors aboard, it was learned that Kosmos-434 was about to reenter. When launched during the era of the Moon Race, it had been thought by Western observers to possibly be an unmanned flight test of a man-rated lunar spacecraft. This judgment was based on the fact that it maneuvered through its orbits in a pattern analogous to that a lunar spacecraft would have to follow near the Moon; also, telemetry signals characteristic only of man-related spacecraft were picked up from it. But at the time it was launched, the Soviets officially referred to it (and three other flights like it) as routine "scientific satellites for research in outer space." Then, after many years of gradually slipping closer and closer to the atmosphere, the satellite finally burned up over Australia.

To allay fears "down under," an official spokesman of the Soviet Foreign Ministry in Moscow assured Canberra that there was no radioactive material aboard Kosmos-434—the satellite was merely "an experimental lunar module!" This, of course, is what Western observers had suspected all along.

"Lunar modules" (in Russian, "lunnaya kabina") is the same term used for the Apollo lunar module and indicates craft that are built and tested to be flown by men, not by robots. The Soviet space secrecy curtain had parted, and another small piece of the true history of the Moon Race was unveiled.

The summer of 1984 was the fifteenth anniversary of the first Apollo landing. It was also the fifteenth anniversary of another lunar flight-related event, which significantly shaped the space exploration paths of Earth's two major spacefaring nations. In 1969, on a launch pad north of Tyuratam in Soviet Central Asia, a giant booster rocket physically twice the size of America's Saturn-V (the "SL-X" or "G-class") was destroyed in a spectacular explosion. Two later launch attempts also failed, sounding the death knell for any Soviet attempt to match or surpass Apollo in the 1970s.

With a little change of luck, the history of manned lunar exploration could have turned out entirely different. This is another wrong impression given by the history books, that things happened the way they did because that was the way they had to happen. Far from it—it was often by the narrowest of margins and by the extremes of cleverness that success was separated from setback and catastrophe.

UNMANNED SOVIET LUNAR PROBES OF THE 1970s

The Soviet lunar program pushed on with a large unmanned soft-lander program, which also began in 1969. By late 1970, success was achieved. Luna-16 landed, picked up soil samples, and returned to Earth. A month later, Luna-17 deposited a "Lunokhod" robot lunar buggy onto the surface for long, slow traverses.

The "scooper" mission was successfully repeated twice more, while at least three missions failed. A second "lunokhod" was landed in 1972, after which the program was terminated. Two spare "lunokhod" modules were modified to act as lunar orbiters. But by 1976, this entire series of three types of spacecraft had ceased.

Why? One possible answer is that funding for Soviet lunar exploration was cut off when the need to "show the flag" *vis-a-vis* American lunar exploration vanished.

There may have also been serious questions about the additional scientific value of more samples. American visitors to the Vernadskiy Institute in Moscow in the mid 1970s noticed that American lunar samples delivered in exchange for Soviet samples had not even been opened, long after the Soviets had obtained them. This suggested a serious bottleneck in the delicate process of extraterrestrial materials analysis, a bottleneck that could have led Kremlin budget cutters to decide that if their scientists could not handle the samples already on hand, there was no use in spending hundreds of millions of rubles to obtain more samples. In addition, more advanced systems were feasible for sample return, and these may have looked more cost-effective.

Photographs of Soviet Venus probes being prepared for launching in the late 1970s show at least one lunar "scooper" vehicle in the background of the assembly hall. This was years after the last known Soviet lunar probe, and it suggests that additional launchings were considered possible but still uncertain. Indeed, one or more launchings may have been made but encountered booster failure.

THE NEXT SOVIET LUNAR PROBE

Soviet lunar scientists regularly attend the annual Lunar and Planetary Science Conference held in Houston every March and throughout the late 1970s kept telling their Western colleagues of their own attempts to obtain funding for advanced lunar missions such as farside landers/scoopers and a polar orbit survey probe. In mid 1984 such approval came, and the following March, at the Sixteenth such conference, Dr. Valeriy Barsukov described what was now on the official Soviet space schedule.

The next project is to be the Lunar Polar Orbiter in 1989–1990. If tradition is followed, it will be Luna-25. Barsukov publicly gave no hint whether it would be a single spacecraft or a series, as is more traditional. Orbital altitude is to be about 100 km. Its aim is to gather information on the chemical and mineralogical composition of the entire surface in order to give a basis for the scientific selection of sites for the return of new samples.

As presented by Barsukov in Houston in March, 1985, the roster of instruments included: a TV camera; gamma spectrometer ("super-pure germanium"); X-ray spectrometer; neutron detectors ("to test the hypothesis of Jim Arnold on polar water ice, and also to map KREEP basalt locations"); spectrophotometer; IR-spectrometer; altimeter; spectrometer of charged particles; a plasma study complex; micrometeorite analysis apparatus; magnetometer; spectrometer of reflected electrons; scintillation counter of reflected electrons; scintillation gamma spectrometer.

No data was given on spacecraft weight, power, or data rate, but available boosters can place up to several tons in the prescribed orbit. The last "Luna" in 1976 weighed 5300 kg pounds on its translunar trajectory. For comparison, a proposed U.S. lunar polar orbiter in the mid 1970s had an injection mass of approximately 500 kg.

But what kind of spacecraft will it be? A major Soviet design theme is commonality and economy, with the same basic bus often appearing for many years in different variations. Since the orbiters of the early 1970s were modified Lunokhod chassis modules now long out of production, a new spacecraft will be needed. One obvious candidate is available: the highly successful Venera-class bus.

Analysis by spacecraft expert and sovietologist David Woods shows that the standard Venera vehicle does not have enough tankage to carry the fuel required for braking into the planned low lunar orbit. However, the addition of jettisonable tanks (a technique used by the Soviet lunar orbiters of the mid 1960s) would solve this problem. In addition, the Venera power system (which depends on full sunlight) would have to be augmented with battery packs for the periodic excursions into the lunar shadow.

Such a program offers the opportunity for cooperation. Western instruments could be included, and Western tracking facilities could be utilized for data communications. The degree of influence of the renewed American interest in lunar exploration on the Soviet decision to fund this new project is uncertain but is justifiably subject to speculation.

Soviet planners could reasonably have assumed that a small U.S. lunar polar orbiter might appear in the early 1990s, so this decision would be consistent with the traditional Soviet desire (which has its American counterpart) to score another scientific first.

POSSIBLE NEAR-TERM FOLLOW-UP LUNAR MISSIONS

Barsukov did not want to discuss follow-up lunar projects, and obviously none have been approved. He did not disclose any specific desires or recommendations from his own office on this subject. However, it should be reasonable to expect that his old desire for farside sampler missions is still alive. Whether such probes would just be rebuilt samplers of the types launched in 1970, or entirely new models, is not known. The 1970-era model was limited to a narrow equatorial region near the Moon's trailing limb, due to severe constraints on the return stage's guidance and propulsion capability. Any new system would have to overcome these constraints.

Another leading possibility for a follow-up lunar mission is a combined operation of rovers (with sample collection capability), coordinated with a return capsule that can be loaded with the cannister filled by the rover. The rover would be landed at sites located by the geochemical surveys from the polar orbiter and could operate for several months before the return module is sent. The final rendezvous on the lunar surface might be difficult but correspondingly valuable.

A third type of mission might involve very high-resolution photography. Soviet military reconnaissance satellites in low Earth orbit weigh about six or seven tonnes and have recently been upgraded to allow direct imaging data transmission back to ground sites. A modified version of this payload might serve well.

SOVIET TRANSLUNAR TRANSPORTATION CAPABILITIES

The feasibility of such near-future options depends on the Soviet transportation capability to lunar orbit. The current standard deep space carrier is the "Proton" (SL-12 in Pentagon parlance, "D"-class in the Western civilian catalogs), while possible new vehicles include the SL-X-16 and the SL-W Saturn-V-class "super booster."

The SL-12 "Proton" (also known as the "D-1") has been operational for more than twenty years. It can carry 42,000 pounds into low Earth orbit, and (in the "D-1-e" variant, which includes a fourth stage) it can inject upwards of 12,000 pounds on a translunar trajectory. More than half of this can be placed into low lunar orbit; at least two tons of payload can be landed softly on the lunar surface.

Although some sources have suggested that the Proton may be phased out in the coming years in favor of the slightly smaller (and still untested) "SL-X-16," other data items suggest otherwise. For one, the annual launch rate has in the last five years climbed from the 6-8 typical of the 1970s to an impressive 11-13, suggesting that additional production facilities (reflecting significant capital investment) have recently come on line. Also, the Soviets have made some attempts to offer the Proton commercially on the world geosynchronous traffic market, an unlikely step if the booster were about to be scrapped.

Late in 1984, the Soviets made a space test flight (called "Kosmos-1603"), which analysts at the time interpreted as demonstrating a new high-energy upper stage, probably fueled with liquid hydrogen. The test was repeated in mid 1985. If Soviet engineers were to proceed with development of J-2-class and Centaur-class engines and were to build new upper stages for the Proton's three-million-pound thrust first stage, the booster could attain impressive levels of performance: up to 70,000 pounds in low Earth orbit and almost 30,000 pounds on a translunar trajectory. This appears to be a very logical line of development. Such an improved Proton could be operational by 1990, even though it probably would not be needed for the announced lunar polar orbiter.

Vague allusions to nuclear-powered upper stages also appear in the Soviet press from time to time. A Nerva-class "space tug" is another viable future option for 1990s Soviet space operations and would promise additional performance improvements based on the tried-and-true Proton first stage.

The purported "SL-X-16" booster, reportedly undergoing final preparations for flight tests in 1985-1986, is supposed to have a payload capacity of about 30,000 pounds in low Earth orbit. There are no suggestions that it has any deep-space applications; analysis of the launch pad structures allegedly indicates that it is designed to be a quick reaction military payload carrier. Since even when operational it will not have anywhere near the performance of the already existing Proton booster, its immediate relevance to future Soviet lunar exploration appears minimal. However, it may have profound long-term relevance, since it is supposedly a component of an even larger Soviet space booster, the "SL-W." According to published Pentagon analyses (backed up by independent European sources), this "SL-W" is to have a payload capacity of up to 400,000 pounds in low Earth orbit. This translates to at least 150,000 pounds on a translunar trajectory.

However, this booster may not become operational until the next decade and may be devoted to more near-Earth military-related or space station-related missions. Still, no matter what the original motivation for its development, its availability in the 1990s could be a major temptation for applying it to a greatly accelerated Soviet manned lunar program.

FUTURE SOVIET MANNED LUNAR ACTIVITY

In the 1970s, Soviet space officials talked freely about possible future manned lunar activity. In 1979, Georgiy Narimanov told a reporter: "I think that stations designed for lunar studies will figure prominently in future space exploration. Using such stations put into lunar orbit, it will be feasible to periodically take cosmonauts to the lunar surface aboard small expeditionary ships. Such stations will be assembled in Earth orbit and then sent to the Moon." Boris Petrov, then head of the "Intercosmos Council," wrote in much the same vein: "In the future there will be a need for a lunar orbital station, which could be assembled in near-Earth orbit and then towed into lunar orbit." Yet these comments probably reflect more the desires than the concrete plans of the officials involved.

Any consideration regarding Soviet manned lunar flight must face the issues of cost versus justification. Chief spacecraft designer Konstantin Feoktistov addressed this question in a newspaper article in late 1984, when he wrote: "One frequently asks when will the Soviet Union send its cosmonauts to the Moon? I answer that question with a question: why do in space what has already been done by others when there is an enormous number of other unresolved problems? If we do this, then it should be at a new, significantly higher level. If we talk about the Moon, this means that it makes no sense to send brief expeditions there and with the same radius of action on the lunar surface. Sufficiently practical and significant goals—scientific and national economic—are needed. And these goals are not yet evident in development of the Moon. Even more so with respect to the expenditures that would be required. Thus, no one plans any longer to go to the Moon."

CONCLUSIONS

Against these conflicting opinions, several observations can be made about the range of future possibilities for Soviet lunar exploration.

1. The Proton booster and reasonable upgradings of it will be available for at least the next ten years and will be capable of carrying between six and twelve tons per launch toward the Moon. This payload weight is more than adequate for advanced samplers, advanced landed rovers, and possible even both on the same mission.

2. The renewed commitment to Soviet lunar exploration, as indicated by the polar orbiter(s), speaks well for the probable approval of future probes to make use of the lunar surface surveys to be produced. Again, sample return associated with some surface mobility is the most reasonable and likely development.

3. While no manned lunar capability appears to be a primary target today, other programs are requiring the development of hardware (such as the Salyut manned module or the SL-W giant booster), which in the 1990s could well be readily, rapidly, and cheaply turned to manned lunar missions. A single Proton launch could carry a team of cosmonauts into lunar orbit and back; an SL-W launch could place a well-stocked Salyut module in low lunar orbit (or the Earth-Moon L1 point, a mission described in recent Soviet technical journals). Modified landers could emplace supplies, shelters, and man-carrying rovers on the lunar surface. Reasonably modified landers of the 1970-1976 generation could serve as stripped-down "space jeeps" to transport cosmonauts between lunar orbit and the surface, perhaps even in a bare-bones EVA mode with the space-suited crewmembers sitting in open space for the several hours required for the transfer.

Insofar as such exploration serves scientific tasks, it benefits the whole world and should thus be encouraged. Since no reasonable military utility for manned lunar flight has been proposed, sharing of American Apollo-era experiences and technology cannot adversely affect the international military balance. But sharing such projects can—and, in my opinion, should—be allowed to affect positively the international diplomatic balance.

Past Soviet Lunar Probes

	Luna (first series): 1958–1960		
1	1958 Jun 22	none	launch failure
2	1958 Sep 24	none	launch faiure
3	1958 Dec 04	none	launch failure
4	1959 Jan 02	Luna-1	passed moon
5	1959 Jun 18	none	launch failure
6	1959 Sep 12	Luna-2	impact
7	1959 Oct 04	Luna-3	photo fly-by
8	1960 Apr 15	none	launch failure
9	1960 2nd qtr	none	launch failure
	Luna (second series): 1963–1968		
1	1963 Jan 30	none	stuck in low orbit
2	1963 Feb 03	none	launch failure
3	1963 Mar 02	none	launch failure
4	1963 Apr 02	Luna-4	payload failure
5	1963 Jul 03	none	launch failure
6	1964 Mar 21	none	launch failure
7	1964 Apr 20	none	launch failure
8	1964 Jun 04	none	launch failure
9	1965 Mar 12	Kosmos-60	stuck in orbit
10	1965 May 09	Luna-5	destroyed on impact
11	1965 Jun 08	Luna-6	payload failure
12	1965 Oct 04	Luna-7	destroyed on impact
13	1965 Dec 03	Luna-8	destroyed on impact
14	1966 Jan 31	Luna-9	sucessful hard landing
15	1966 Mar 31	Luna-10	lunar orbiter
16	1966 Apr 30	none	launch failure
17	1966 Aug 24	Luna-11	payload failure
18	1966 Sep 25	none	launch failure
19	1966 Oct 22	Luna-12	lunar orbiter
20	1966 Dec 21	Luna-13	successful hard landing
21	1968 Feb 07	none	launch failure
22	1968 Apr 07	Luna-14	pre-Zond nav, comm tests
	Lunar Zond: 1967–1970		
1	1967 Mar 10	Kosmos-146	stuck in low orbit
2	1967 Apr 08	Kosmos-154	stuck in low orbit
3	1967 Nov 22	none	launch failure
4	1968 Mar 02	Zond-4	phantom moon fly-by
5	1968 Apr 22	none	launch failure
6	1968 Sep 14	Zond-5	flyby & splashdown
7	1968 Nov 10	Zond-6	flyby & USSR landing
8	1968 Dec 06?	none	cancelled manned launch
9	1969 Aug 07	Zond-7	flyby & USSR landing
10	1970 Oct 20	Zond-8	flyby & splashdown
	Luna (third series): 1969–1976		
1	1969 Jan 20	none	launch failure
2	1969 Apr 22	none	launch failure
3	1969 Jun 05	none	launch failure

4	1969 Jul 13	Luna-15	destroyed on impact
5	1969 Sep 23	Kosmos-300	stuck in low orbit
6	1969 Oct 22	Kosmos-305	stuck in low orbit
7	1970 Feb 06	none	launch failure
8	1970 Aug 08	none	launch failure
9	1970 Sep 12	Luna-16	success-sampler
10	1970 Nov 10	Luna-17	success-lunokhod
11	1971 Sep 02	Luna-18	destroyed on impact
12	1971 Sep 28	Luna-19	success-orbiter
13	1972 Feb 14	Luna-20	success-sampler
14	1973 Jan 08	Luna-21	success-lunokhod
15	1974 May 29	Luna-22	success-orbiter
16	1974 Oct 28	Luna-23	payload failure (sampler)
17	1975 Oct 15	none	launch failure
18	1976 Aug 09	Luna-24	success-drill sampler
19	1978 ?	none	cancelled? (sampler)

SLX-X ("G-class") Blow-ups: 1969–1971

1	1969 Jul 04?
2	1971 Jun 24
3	1972 Nov 22

Lunar Module (LEO tests): 1969–1971

1	1969 Nov 28	none	D-1 launch failure
2	1970 Nov 24	Kosmos-379	A-2
3	1970 Dec 02	Kosmos-382	D-1
4	1971 Feb 26	Kosmos-398	A-2
5	1971 Aug 12	Kosmos-434	A-2

The launch failure dates are reconstructed from declassified U.S. Government documents and from analyses by the British Interplanetary Society; the author considers them reliable. Soviet spokesmen have never admitted any launch failures and in fact explicitly deny them.

LEGAL RESPONSES FOR LUNAR BASES AND SPACE ACTIVITIES IN THE 21ST CENTURY

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The Lunar Bases and Space Activities of the 21st Century Symposium from which this volume resulted made a very persuasive case for a lunar base as the next logical step in the exploration and use of outer space in the next century. The feasibility of this goal—a lunar base and human inhabitation of the planets—was presented in great detail from the science, technology, and policy viewpoints. One of the great unknowns, however, is the legal response to a lunar base initiative. Building from the general principles of the 1967 Outer Space Treaty, a whole range of legal regimes is possible.

The range of legal regimes is a distinct advantage as manned space activities in the 21st Century will be like no others. The problems must be defined and models to solve them chosen. These actions should reveal more clearly the necessary legal underpinnings. Successful completion of the U.S. space station will provide considerable experience at working in the unique environment of space. It will also test the legal relationships between the U.S. and its partners (U.S. nongovernmental users, foreign governments, and foreign commercial participants) in terms of their efficacy in promoting and safeguarding respective rights and interests. Any legal regime touching on lunar activities must meet the realities of that environment, if the feasibility of exploiting lunar resources is to be proved and the benefits made available to the international community.

CONCERNS

In all the rhetoric about lunar activities and legal regimes, two major concerns emerge: (1) How can lunar resources be used on the scale necessary to support lunar and other space activities in the face of the explicit prohibition of national appropriation under international space law? and (2) How can the role and rights of private enterprise be guaranteed?

The national appropriation prohibition is most simply stated in the 1967 Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies (Outer Space Treaty). Specifically, Article 2 states that "outer space, including the Moon and other celestial bodies, is not subject to national appropriation by claim of sovereignty, by means of use or occupation, or by any other means." This document is in effect the "Magna Carta" for the exploration and use of outer space, the Moon, and celestial bodies. It has been ratified by more States than any other general space law treaty (Lee and Jasentulyana, 1979). Most importantly, its general principles have been accepted by over 75 States, including the major space powers, in particular the U.S., U.S.S.R., France and the other member States of the European Space Agency, Japan, and China.

An identical prohibition is contained in Article 11 of the Agreement Governing the Activities of States on the Moon and Other Celestial Bodies (Moon Agreement), except that "any" has been added before "claim" (U.S. Congress, Senate Committee on Commerce, Science, and Transportation, 1980). The Moon Agreement was open for signature on December 18, 1979, and entered into force on July 11, 1984. However, its ratifying States to date have not been those nations with extensive space programs. By November, 1985, the Moon Agreement had been ratified by Austria, Chile, the Netherlands, the Philippines, and Uruguay. Domestic opposition has been sufficiently strong to prevent U.S. ratification of the treaty. The U.S.S.R., in turn, usually becomes party to a space treaty only when the U.S. does. Nevertheless, the nonappropriation principle as stated in the Outer Space Treaty is sufficiently normative in character so as to be considered a valid principle of international law in both treaty and custom (Joyner and Schmitt, 1984).

Clearly it is permissible to use lunar materials for scientific research when results of that research are disseminated to the public and international scientific community. This has already been done with lunar rocks brought back to Earth by the U.S. and U.S.S.R. Similarly lunar resources may be used in experimental and pilot projects to prove a technology or the feasibility of a new development. A claim to a portion of the Moon or its resources, however, is not lawful under existing space law. Proponents of private enterprise argue that without such an internationally recognized national claim to lunar resources (in effect a valid title to the resources) commercial development will not be possible (Dula and Lingl, 1984).

The roles and right of private enterprise will always be derived from national law (Finch and Moore, 1985). International space law has already recognized that space activities may be conducted by organizations other than governmental agencies. The Outer Space Treaty, in Article 6, makes States internationally responsible for national activities in space whether conducted by governmental agencies or nongovernmental entities. These nongovernmental entities, in turn, must have authorization and continuing supervision by the appropriate State. The amount of that authorization and supervision is left to the State alone. Even with an international organization conducting activities in space, treaty compliance must be ensured by both the international organization and the member States who are party to the Outer Space Treaty. International space law does not prohibit commercial activities in space. Instead it recognizes that such activities will take place, but always with a State responsible for those actions. Therefore, whatever role private enterprise will have on the Moon, it must look to national governments to promote, support, and protect it.

LUNAR ENTERPRISES

A lunar base in the 21st century is a goal with a timeframe stretching over 50 years from now. A lot will happen in that time, principally in science and technology but also in economics and international affairs. A series of breakthroughs, or even just one, could change the whole equation for achieving the goal. The best way is not yet written in stone. Therefore, it will always be necessary to study and keep options open.

National activities in space will continue to dominate the field for the next dozen years to come. Similarly, the present rationale for a lunar base is strictly scientific and as a logistic base for further planetary exploration, *e.g.*, to undertake a mission to Mars, activities accomplished almost exclusively by government support. Commercial development is not expected until the last half of the 21st century.

As all the possible scientific uses of the Moon can only be projected, so the full range of commercial opportunities can only be imagined (Finch and Moore, 1985). Most often it is proposed that lunar and asteroid resources be processed for the raw materials to build large structures in space. These structures in turn would (1) support the collection of solar energy for relay to Earth for conversion into electricity, (2) provide habitats for the necessary personnel who may be in space for a limited or permanent duration, and (3) include facilities to manufacture products better made in space or simply unavailable on Earth. On the Moon itself, a profitable enterprise might be to simply transport and house tourists who wish to journey to the Moon. The most profitable uses of the Moon are most likely ones not yet envisioned.

MODELS

The implications of such enterprises are that each specific activity will have its own legal requirements to succeed. With a specific activity in mind, a model method of operation could be chosen and the most appropriate legal rules determined. Over the years, numerous uses have been made of space and its resources without national appropriation. To date these resources have been mainly intangible, *e.g.*, the radio frequency spectrum and slots on the geostationary orbit for communication satellites. Various models of operations have evolved and most contain international elements. As such, the legal arrangements are not "national" appropriation, but the international ordering of resources for use on a nondiscriminatory basis.

Following are just a few models for a lunar base operation:

1. A U.S. enterprise with participation and funding from other participants, as planned for the U.S. space station
2. Independent activities and expeditions coordinated through an established international organization
3. Bilateral endeavors
4. User-based international organization along the line of Intelsat and Inmarsat
5. A truly transnational enterprise, such as the one for building a pipeline between Europe and the U.S.S.R.
6. A consortium of private business concerns to conduct the particular space activity, as U.S. companies built and operate the Alaskan pipeline
7. An international authority that franchises States or private enterprises to exploit resources under specified conditions, such as the International Seabed Authority for exploitation of minerals under the high seas.

Certainly with any space enterprise involving the U.S., private enterprise is already a partner as the contracted supplier of goods and services. Already private enterprise competes for the contracts to supply the ground and space segments of Intelsat. In this particular model, the participation of private enterprise in the international organization itself is left to the State, which may designate any entity it wishes as its representative. Access to the service of the organization provided through the designated entity is similarly left up to the State (Finch and Moore, 1985).

MECHANISMS

Based on the desired model, the necessity of and mechanisms for legal rules may be determined. Where coordination is through an existing organization, procedures in place or a specifically convened meeting of the members should suffice. Bilateral efforts or national endeavors with multilateral participation can be conducted through normal channels of international discourse. A consortium of private businesses or a specially formed transnational enterprise would probably reach agreement among themselves, and then publicly seek any needed permissions, financing, or goods and services. The influence of the funding sources should not be underestimated at either the national or private level.

A user-based international organization like Intelsat would entail specifically convened negotiations among the interested States to establish the desired entity. Arrangements would most likely include decisions by weighted voting based upon investment in and use of the enterprise. As an example, Joyner and Schmitt suggest an organization called "INTERLUNE" for the provision of "lunar base facilities, services and access of high functional potential, quality, safety, and reliability to be available on an open and nondiscriminatory basis to all peaceful users and investors (Joyner and Schmitt, 1984). In their view, the organizational concept would be tailored to provide cooperative management of a lunar base to the benefit of its members, users, and investors. INTERLUNE would provide such management through "sharing international opportunities, rather than through unilateral control by any one nation or set of competing nations."

In Article 11, the Moon Agreement envisions negotiations among its States Parties under United Nations auspices to establish an international regime, including appropriate procedures, to govern the exploitation of the natural resources of the Moon "as such exploitation is about to become feasible." Such a conference would give form and substance to the concept of the common heritage of mankind, rather than philosophical speculation (U.S. Congress, Senate Committee on Commerce, Science, and Transportation, 1980). A review of the Agreement itself can take place in 1994 (ten years after entry into force), or as soon as 1989 if one-third of the States Parties so request and a majority concur, as provided by Article 18.

IN CONCLUSION

Conceivably, a lunar facility could be established, lunar resources extracted for their component materials on a profit-making basis, and other activities commenced using the Moon as a base, with no further legal notice on an international scale. Informal agreements among the interested States could remove any points of contention and the individual countries would see to the interests of their individual entities, be they governmental or private. This is an optimal scenario, but not a likely one. Too many questions have been raised in both the public and private sectors for any State to proceed with a lunar base initiative without taking into account the interests of other potential users and the international community.

It must be stressed again that private or commercial entities must look to their national governments and their national laws for the most effective promotion of their interests. If what is wanted is a sure set of rules, then private enterprise must make their views known to the respective governments at every stage of a space initiative from planning to operation. The most effective input is that given during the planning stage. However, flexibility must be included in any final arrangements as circumstances change in the actual operation of a space station or lunar base. In the U.S., for example, such input may be made by membership in advisory groups and delegations, testimony before Congress, the conduct of seminars and meetings of interested government and nongovernment personnel, and even the release of private studies.

All these actions facilitate the communication of private industry's needs for effective participation in space activities, be they near-Earth, in geostationary orbit, on the Moon or beyond. International space law requires little beyond peaceful uses in accordance with international law on a nondiscriminatory basis, with government authorization and supervision and the dissemination of results. There is no rule of law precluding profit or private enterprise from space.

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EXTRATERRESTRIAL LAW AND LUNAR BASES: GENERAL LEGAL PRINCIPLES AND A PARTICULAR REGIME PROPOSAL (INTERLUNE)

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Contemporary international law recognizes the validity and relevance of extraterrestrial legal principles to outer space activities, including the conceivable establishment of permanently manned bases on the Moon. By applying the legal principles of free access to outer space, non-appropriation of celestial bodies, use of space for peaceful purposes only, and development of outer space for mankind's benefit, this paper suggests a possible regime—INTERLUNE—for governing international activities on the Moon. Modeled on the INTELSAT system, INTERLUNE would be comprised of an Assembly of Parties, a Board of Governors, a Board of Users and Investors, and a Director General. INTERLUNE represents a model organization tailored to facilitate cooperative international management of a lunar base to benefit its member states, users, and investors. INTERLUNE could provide such management through a sharing of both sovereignty and opportunity. Importantly, such a regime would enhance international cooperation by precluding the possible usurpation of control over the Moon and its natural resources by any one state or group of competing states.

INTRODUCTION

Serious contemplation of returning to the Moon necessarily invites critical consideration of assessing and evaluating the international legal implications of performing that mission. Relatedly, there is also the fundamental priority of considering what type of regime should be formulated to carry out activities on the Moon peacefully for the benefit of all peoples.

This paper therefore aims to achieve two broad purposes. First, it identifies and sets out in clearer relief the relevant extraterrestrial legal principles that currently are deemed applicable to establishing and operating lunar basing facilities. Second, it seeks to propose a prospective regime, "INTERLUNE," for overseeing international activities on the Moon peacefully, efficiently, and in accord with the recognized principles of extraterrestrial law. While obviously not intended to be either a panacea or a definitive legal schema for managing man's affairs on the Moon, the "INTERLUNE" proposal hopefully will stimulate serious discussion and reasoned debate about the nature of a lunar regime, as well as the appropriate political, economic, and legal prerequisites for its promulgation.

PRINCIPLES OF EXTRATERRESTRIAL LAW

During the past 25 years, extraterrestrial law, or space law, has become a recognized and indeed vital branch of international law (Christol, 1982; Lachs, 1972; Kolosov, 1974; Williams, 1981). Though admittedly specialized and directly pertinent only to the conduct of a relative paucity of states, at least four major multilateral treaties have been negotiated and are now legally in force: (1) the Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies; (2) the Agreement on the Rescue and Return of Astronauts, and the Return of Objects Launched into Outer Space; (3) the Convention on International Liability for Damage Caused by Space Objects; and (4) the Convention on Registration of Objects Launched into Outer Space. All these agreements today are active facets of international law, to which both the United States and the Soviet Union, as well as other major space-resource states, have legally obligated themselves as parties. Consequently, these four relevant treaties compose the contemporary international legal framework for space law and, coincidentally, for implementing a lunar base program.

Of these agreements, the 1967 Outer Space Treaty furnishes the most far-reaching contributions for fashioning extraterrestrial law. Today 86 states are parties to this agreement. Moreover, at least five fundamental principles of space law can be distilled and crystallized from the Outer Space Treaty's operative provisions. Significantly, these cardinal principles have been accepted in the practice of states as constituting legally salient norms for regulating the conduct of space-related activities. Put succinctly, these principles assert that: (1) space, including the Moon and other celestial bodies, is the province of mankind and should be developed for its benefit (Article I); (2) space, including the Moon and other celestial bodies, should be free for exploration and use by all states. Equality in and free access to all areas shall be available to all states, and freedom of scientific investigation shall be ensured to any interested party (Article I); (3) space, including the Moon and other celestial bodies, is "not subject to national appropriation by claim of sovereignty, by means of use or occupation, or by any other means" (Article II); (4) space, including the Moon and other celestial bodies, shall be used exclusively for peaceful purposes. Accordingly, "[t]he establishment of military bases, installations and fortifications, the testing of any type of weapons and the conduct of military maneuvers on celestial bodies shall be forbidden." Of especial import, "States parties to the [Outer Space] treaty undertake not to place in orbit around the Earth any objects carrying nuclear weapons or any other kinds of weapons of mass destruction, install such weapons on celestial bodies, or station such weapons in outer space in any other manner" (Article IV); and, (5) international law as formulated here on Earth does extend extraterrestrially to space and celestial bodies. Hence, general principles of law in the Outer Space Treaty embody expectations of the parties, and also articulate the paramount recognition that all mankind possesses a common interest in the progressive exploration and use of outer space for peaceful purposes (Article III).

These five fundamental principles undergird the corpus of extraterrestrial law and have developed only since 1957. Of special note, they have been derived from the traditional sources of international law, namely, international treaties and conventions, customary state practice, so-called "general principles of law," and the writings and opinions of legal scholars and jurists. These principles were initially expressed in "codified legal form" in the 1967 Outer Space Treaty but have been subsequently integrated as cardinal provisions into the later multilateral space-related conventions. In essence they form the foundation upon which extraterrestrial law rests, and thus concomitantly become the critical legal considerations that must be accounted for in the actual establishment of future lunar basing facilities (Adams, 1968; Kopal, 1973; Lachs, 1972; Christol, 1982; Menter, 1979; Kulebyakin, 1971).

Inasmuch as these fundamental principles of extraterrestrial law are all expressed in the Outer Space Treaty, this agreement may be properly regarded as a covenant of outer space law. Respective to the Moon, however, one principle stands out as being more significant legally and politically than the others, namely, the non-appropriation provision in Article II. At present, this principle asserts that no portion of the Moon or other celestial bodies is susceptible to any state's sovereign claim, national title, or territorial jurisdiction. In short, there can be no private or state ownership of the Moon (or for that matter, of any other celestial body). This point requires some clarification. Utilization of the Moon's resources—be it removal of Moon rocks and taking other samples or the implementation of techniques to extract oxygen from the lunar soil—is not in question; such scientific and life-support activities would be permissible under the legal provisions of the Outer Space Treaty. It is the national appropriation of the Moon as sovereign territory belonging to some polity on Earth that is unacceptable. As the direct consequence, the legal status of the Moon was transformed from a condition of *terra nullius* (*i.e.*, vacant land that belonged to no one and therefore was available to claim by anyone) to that of *res extra commercium*, the status of legally not being susceptible to any possibility of national appropriation. For the present, therefore, effectuation of national sovereignty on the Moon perforce has been eliminated from legitimate consideration (Adams, 1968; Bhatt, 1968; Christol, 1982; Williams, 1981; DeKanozov, 1975).

THE MOON AND "THE COMMON HERITAGE OF MANKIND"

The most recent international effort aimed at defining more precisely the Moon's legal status culminated in the negotiation in 1979 of the Agreement Governing the Activities of States on the Moon and Other Celestial Bodies, more commonly known as the "Moon Treaty." In general, the Moon Treaty, which only recently came into force, merely reaffirms and only slightly extends the existent corpus of extraterrestrial law. However, the glaring exception to these progressive developments is found in Article XI of the Moon Treaty, which: (1) asserts that the Moon and other celestial bodies are the "common heritage of mankind"; (2) reiterates that the Moon is not subject to national appropriation; (3) stipulates anew that the surface and subsurface, inclusive of *in situ* resources, may not become the property of any state, international organization, non-governmental entity, or natural person; (4) posits that parties would enjoy non-discriminatory access to the Moon; and (5) asserts that at the time when exploitation of the Moon becomes feasible, states party to the the treaty will establish an international regime to "govern exploitation of the natural resources." In this respect, the regime purportedly would operate to ensure orderly development and rational management of lunar resources. Less clear and more polemical, however, is the regime's attendant purpose of facilitating an equitable sharing of benefits derived from those resources for parties, whereby "special consideration" would be given to "the interests and needs of the developing countries as well as the efforts of those countries which have contributed either directly or indirectly to the exploration of the Moon" (Christol, 1980; Cocca, 1974; Dekanozov, 1978; Smith, 1980; Larschan and Brennan, 1983).

It is primarily because of this "common heritage of mankind" (CHM) provision that the Moon Treaty only recently entered into force in late 1984 by securing ratification by the requisite number of five states—Austria, Chile, Netherlands, the Philippines and Uruguay—none of which is a significant space-faring power. Furthermore, it is the CHM notion that has fostered confusion about the precise status of the Moon under contemporary international law.

Respective to the Moon, the most that can be posited about the status of CHM as a legal concept is that it *may* inculcate an emergent principle of international law. At present, CHM is a notion containing more latent than apparent actual value, with more nascent and potential legal ramifications than manifest implications or binding obligatory force. As a consequence, CHM remains less than a bona fide principle of international law, posing only inferential relevance to the Moon's legal status (Gorove, 1972; Kosolov, 1979).

The upshot of these observations suggests that certain general principles of extraterrestrial law have been established, are recognized in the practice of states, and are currently applicable to the Moon (Galloway, 1981; Matte, 1978). Nonetheless, space law remains in a process of continuous evolution, with much still left open to diverse national interpretation. Notwithstanding this caveat, broad international consensus maintains that outer space, the Moon, and other celestial bodies should be open for exploration and use for the benefit of mankind, that principles of international law are applicable to these opportunities, and that the Moon and other celestial bodies should be used exclusively for peaceful purposes. To these ends, the Moon and other celestial bodies are today regarded as being legally immune from sovereign claim or territorial acquisition (Dolman, 1981).

Yet, extraterrestrial law is not static. It inculcates an evolutionary process that is capable of growing to meet new challenges and adapting to formulate new norms. Very likely, the international law pertaining to outer space will continue to evolve as new technologies are developed and further exploration is undertaken (Dula, 1979; Menter, 1983; Smith *et al.*, 1983; Vassilovskaya, 1974). Certainly in this regard, establishment of a lunar basing facility will engender widespread international concern about the type of regime necessary for managing various activities on the Moon. The next section of this paper turns to address this critical legal concern. It formulates a regime of international law that is consistent with both accepted principles of space law and the philosophy of CHM but avoids the practical difficulties of the more extreme proposals for the implementation of CHM in law.

THE INTERLUNE CONCEPT: USER-CONTROLLED INTERNATIONAL MANAGEMENT SYSTEM FOR A LUNAR BASE

The existing regimes for space discussed above clearly place significant legal constraints on governments interested in the establishment of a permanent lunar base. The obvious practical difficulties that the world is experiencing with one-nation, one-vote international organizations also suggest that notable pragmatic constraints exist for states desiring to participate in founding such a base or settlement. Fortunately, international experience has provided a successful model of a high-technology management system that meets the legal, operational, and self-interest constraints attendant to international operations in space. That model is INTELSAT, a user-based management system that works to coordinate operation of international communications satellites (Smith, 1980).

In this paper, a version of the INTELSAT model is suggested as being especially appropriate for the international management of a lunar base. It is submitted here that "INTERLUNE," as the organization is termed, will aptly satisfy the aforementioned legal constraints, as well as hold consistent with the principles of free enterprise that are shared by the world's democracies. More importantly, INTERLUNE would bring into the management of a lunar base those states and other interests that evince the greatest motivations for ensuring successful implementation of that managerial system. INTERLUNE does not require that sovereignty be given up in space; it does not require that free-enterprise opportunities be abandoned in space; it merely requires that sovereignty and opportunity be shared.

Technological advancements have produced a trend toward recognizing a "common heritage of mankind" in certain international resources. This trend is most apparent in negotiations regarding the resources of the sea and outer space. It indicates a general realization that states possess common interests in sharing benefits from the exploitation and environmentally sound use of those resources.

The Moon can become a common heritage resource for mankind. However, without a feasible administrative system and a peaceful management environment, lunar opportunities will remain unavailable and moribund. An institutional arrangement should be possible that would vest operation and control of lunar bases in an organization comprised of states that actively participate in creating such bases, in association with users of the bases or investors in their operations. Such states and related entities would be united by a common bond of policy and purposes focused on the technical and financial success of the enterprise.

INTERLUNE'S MANAGEMENT STRUCTURE

The conceptual advantages of a regional organization such as INTERLUNE could be realized only if the actual institutional structure were designed to provide an equitable system for various interests to exert influence and control, as well as to furnish efficient and proper management of the base.

The main functioning bodies INTERLUNE is comprised of are the Assembly of Parties, the Board of Governors, the Board of Users and Investors, and the Director's Office. The

Assembly of Parties would exert policy authority over the Board of Governors, which would in turn exert functional authority over the Director General. The Board of Users and Investors, operating within the policy framework set down by the Assembly of Parties, would develop recommendations regarding operational issues affecting the Board's interests. These recommendations would then be presented to the Board of Governors through the Board of Users and Investors' formal representatives on that Board.

The basic national membership of INTERLUNE would be constituted in the Assembly of Parties. Each Assembly member's interest in INTERLUNE would be proportional to its investment of equivalent capital in the creation and initial operation of the lunar base. A member's proportional interest at the beginning of any operating year would set the number of votes to which that member would be entitled during deliberations of the Assembly of Parties.

The principal function of the Assembly of Parties would be to establish policy within the legal parameters of an INTERLUNE charter previously negotiated and agreed to by its member states. Under its charter, INTERLUNE might express as its prime goal "the provision of lunar base facilities, services and access of high functional potential, quality, safety, and reliability to be available on an open and non-discriminatory basis to all peaceful users and investors." As ancillary goals, INTERLUNE would be expected: (1) to seek a return on investment in its assets and operation, not exceeding a stipulated annual percentage, while remaining consistent with meeting its primary goal; and (2) to ensure the neutrality and security of activities under its jurisdiction. In addition, the Assembly of Parties would supply a mechanism and forum for the peaceful settlement of disputes relating to provisions in the INTERLUNE Charter or any resultant policy derived therefrom.

Several specific mandates for the Assembly of Parties would be incorporated in the INTERLUNE Charter, including the following: (1) to provide general policy guidelines and specified long-term objectives to meet the primary goal of INTERLUNE; (2) to establish general rules concerning rates of charge for use of INTERLUNE's facilities and services on a non-discriminatory basis; (3) to consider and adjudicate complaints submitted to it by states, competent international organizations, users and investors; (4) to maintain a body of laws, rules, procedures, and instructions for dealing with normal operations and dispute settlement; and (5) to establish general guidelines for the financial participation of potential investors in INTERLUNE.

The Assembly of Parties would be comprised of one representative from each member state. Decisions on all matters would be taken by three-quarters majority vote.

The Board of Governors would have the responsibility for the operation and maintenance of INTERLUNE's facilities and services, as well as for the design, development, construction, improvement, upkeep, and general operation of INTERLUNE. As conceivably defined, some specific duties of the Board of Governors would include: (1) to adopt policies, plans, and programs aimed at enhancing and sustaining the environmentally balanced operation of INTERLUNE; (2) to create and implement annual budgets; (3) to establish periodically rates of charge for utilizing INTERLUNE's facilities and services in accordance with the general rules set by the Assemby of Parties; (4) to solicit capital; (5) to appoint the Director General and to approve senior staff appointments; and (6) to arrange contracts with a state, organization, or institution relating to the performance, functioning, and operation of INTERLUNE's facilities and services.

The Board of Governors would be comprised of up to 15 members. One governor each would be drawn from those states, or groups of states, who have made major space investments in support of INTERLUNE (*e.g.*, the United States, the Soviet Union, and the European Space Agency); two governors would be selected to represent the Board of Users and Investors; and the remainder would represent those states, or voluntary pairs of participating states, that would qualify according to a formula based on actual commitment of resources in INTERLUNE's behalf.

Voting participation by the Board of Governors would be defined by the Assembly of Parties and the relationship set for Assembly deliberation. The governors should endeavor to make all decisions by consensus. However, if consensus is not possible, governors would each participate in the deliberation process commensurate with the voting proportion of their respective states. A three-quarters majority of the total voting participation would be necessary for substantive decisions, while a simple majority would be necessary for procedural decisions. The governors representing the Board of Users and Investors would have voting particpation proportional to the cost paid to, or capital invested in INTERLUNE.

INTERLUNE's Board of Users and Investors would have the responsibility to advise INTERLUNE on all matters of policy and operations that affect the use and financial viability of INTERLUNE's facilities, services, management efficiency, and future explansion. Initially, all committed users and investors would be invited by the Assembly of Parties to a Charter Conference to establish the organizational structure of the Board of Users and Investors. Upon the Charter's acceptance by three-quarters majority of the users and investors and ratified by the Assembly of Parties, the Board of Users and Investors would receive staff and financial support from INTERLUNE, and as aforementioned, would be granted two representatives on the Board of Governors.

The executive body, or staff component, of INTERLUNE would be headed by the Director General. Among his specific duties would be (1) to serve as the legal representative of INTERLUNE and be responsible for all administrative and personnel functions; (2) to contract out to various competent entities technical and maintenance functions associated with INTERLUNE's operation, with due regard to cost and consistency *vis-a-vis* competence, effectiveness, and efficiency (as provided for in the Charter agreement, such entities would be comprised of various nationalities, or could be an international corporation owned and controlled by INTERLUNE); and, (3) to serve as the principal negotiator on behalf of INTERLUNE.

Ultimately INTERLUNE would require the establishment of a dispute settlement system. A first level of this system might be arbitration under the auspices of the Assembly of Parties. A second level could be a judicial tribunal, created by the Assembly of Parties, which would serve as a final court of appeals for unresolved disputes, as well as for criminal or civil violations under INTERLUNE's jurisdiction. Importantly in this regard, adoption of a code of criminal and civil law for INTERLUNE would of necessity be agreed to in an addendum to its basic charter, being subject to modification of amendment only by the Assembly of Parties voting through their secondary vote procedure.

THE IMPLEMENTATION OF INTERLUNE

The legal initiation and viable implementation of any international idea or organization never comes easily or simply. INTERLUNE will be no exception. Nonetheless, activating INTERLUNE clearly will remain possible, so long as the major space-faring powers—particularly the United States—sustain unequivocal commitment to the establishment of a lunar base, with the attendant political will to search out and secure international participation in such an endeavor. To do otherwise would seem regrettable in that a great opportunity for increased legal cooperation and international trust among traditionally competing states would be lost. Thus, viable implementation of the INTERLUNE regime in all likelihood would hinge upon substantial participation by the United States.

Presuming commitment to a lunar base by the United States, the next logical step toward implementation ostensibly would be the convening of an international conference to consider and negotiate a draft INTERLUNE Charter. All states would be invited to send representative delegates or observers, and potential users or investor entities should be invited as observers, as well as encouraged to participate as members of official delegations.

A critical consideration lies in the respective roles that the Soviet Union and the developing states should play in the creation and implementation of the INTERLUNE regime. To facilitate their participation in INTERLUNE, the opportunity should be made so attractive that they cannot refuse. Such an offer is inherent in, first, an unequivocal commitment by the United States, Western Europe, and Japan in the project; second, a manifest willingness by all parties to share sovereignty, opportunity, and technology; and third, a clear articulation of the direct economic, legal, and political benefits accruing to all participant states. Once an established and successful reality, INTERLUNE would surely attract additional states that at first may have been reluctant to participate. Though purportedly conceived as an international self-regulating monopoly, INTERLUNE should always remain open to new members and investors. In this manner, the regime's humanistic goals, as well as its specific economic and technical purposes, could be most fully achieved in the interest of all mankind.

CONCLUSION

Existent extraterrestrial law, as well as the fundamental interests of space-faring states, are consistent with the inception of a user-based international organization for managing a lunar regime. Through an Assembly of Parties, a Board of Governors, a Board of Users and Investors, and a Director General, INTERLUNE would meet its primary goal of providing open access to and available facilities and services for a lunar base founded on principles of non-discrimination and peaceful purposes only. The internal structure and guiding philosophy of INTERLUNE allows for all participants to share representation in decisions affecting its activities; additionally, moreover, INTERLUNE would assure effective and responsive management of the lunar facility and the Moon's natural environment.

The INTERLUNE proposal is a model organization concept tailored to provide cooperative management of a lunar base in order to benefit its members, users, investors, and, indeed, all mankind. Significantly, INTERLUNE would provide regime management through sharing both sovereignty and opportunity, rather than through unilateral control by any single state or set of competing states. Surely this is the extraterrestrial legal precedent that we wish to establish for mankind at the now not-so-distant shores of the new ocean of space.

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LUNAR BASE: LEARNING TO LIVE IN SPACE

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Going back to the Moon to establish a permanent base presents a social as well as a technical challenge. The experience of small, isolated groups in highly stressed environments points to the need for appropriate systems of social organization to enable groups to work safely and productively in space. Based on a survey of the literature and on experience working with small groups as an anthropologist, suggestions are put forward as to the need to: (1) make social research and planning part of the lunar base program; (2) make learning how to live in space an iterative effort, starting now with the space station and carrying on beyond the lunar base; (3) simulate space communities in realistic mock-ups on Earth before testing them out in space; and (4) make self-design of space communities by those who will actually live in space a basic element of planning.

We need to pay attention to the nature of the social systems to be created with the first lunar bases. The composition, organization, and governance of those first lunar communities will be vital to their success and, ultimately, to the goal of learning to live in space. We should start now on a research and development program directed toward developing social systems designed so that people can safely and productively live and work on the Moon.

To highlight this need, let me cite an example drawn from the history of Antarctic exploration. In the Antarctic summer of 1911 two teams raced for the then unconquered South Pole: the British under the command of Robert Falcon Scott of the Royal Navy, and the Norwegians, led by the veteran explorer Roald Amundsen. Both made it to the Pole, but only Amundsen and his men, who got there first, made it back alive. Scott and his men perished on the terrifying march back (Huntford, 1984).

Amundsen, an accomplished Arctic explorer who had been the first to force the Northwest Passage, did everything right. Combining elements of western technology with Eskimo-style clothing and dog sleds, and with Nordic skiing techniques, his race to the Pole and back went like clockwork. His men were well chosen and trained, and their individual roles and the organization of the team were meticulously planned and rehearsed. In contrast, Scott, although he had already led one Antarctic expedition, paid little heed to the merits of Eskimo and Nordic Arctic technology, experimented fruitlessly with ponies and tractors, and finally settled on the killing strategy of "man-hauling" sledges across the glaciers. What is more, many of Scott's men were ill-chosen and inadequately trained, and their duties as well as the structure of the team were not made clear. According to a recent biographer (Huntford, 1984), Scott followed a tenet then popular in the Royal Navy: "an officer does not worry about details but stands ready to improvise."

This race to the South Pole illustrates how crucial appropriate planning and preparation in both hardware and human relations are to the success of hazardous exploratory expeditions. NASA, of course, passed that test in the Apollo program. The question now is, how will it do for the return to the Moon?

No one seriously advocates going back to the Moon the way it was done 15 years ago. We now want to develop permanent bases there. This new conception requires technological developments beyond those used in Apollo—reusable space transport, closed or nearly closed ecological life support systems, and techniques for mining and processing lunar ores, to name several of the most obvious. Just as hardware appropriate to staying on the Moon has to be developed, so, too, do we need to develop an appropriate sociology for living and working on the Moon.

To be sure, the astronauts and cosmonauts have done a superb job in pioneering manned spaceflight. But, as representatives from both groups admit (Bluth, 1981; Carr, 1981), the problems of living and working together in space for prolonged periods are far from solved. For example, Gerald Carr, commander of the 84-day Skylab mission, has gone on record that he expects that "the sociological problems will prove to be more difficult to solve than the technological ones." Gone are the days when space operations involved just a few male astronauts, alike in background and training, going out for short-duration spaceflights. On the Moon, life will get much more complicated.

First, a lunar base, or at least a mature one, will involve far more people than have hitherto been together in space for long periods. Second, lunar base inhabitants are likely to be heterogeneous. For example, a community might include scientists, technicians, and medical personnel as well as more traditional astronauts; it might have a number of women as well as men; people from several nations are likely to be represented; and, private sector employees may work alongside civil servants and military personnel. Third, all these people will have to stay together for many months, perhaps a year or longer, in confined quarters located in an unearthly environment separated from Earthside family, friends and familiar sights, sounds and smells. Judging from partly analogous situations in the Antarctic and elsewhere, all this will add up to significant stresses and strains on every individual's psyche and on the social fabric of the group (Bluth, 1984; Connors *et al.*, 1985; Helmreich *et al.*, 1980). A social organization designed to minimize such stresses and strains, or at least one adapted to dealing with them, would help ensure that a lunar base would be a successful and productive community.

During the 1960s NASA did commission a considerable number of studies of naval and Antarctic analogues to prolonged space missions, and sponsored still other studies of how men adapted to living in cramped and hazardous undersea habitats. These were directed toward identifying the social-psychological problems that might be encountered on prolonged space missions and suggesting strategies for dealing with these. Yet, by the late 1970s enthusiasm for such studies fell to a low point, and relatively few new ones were being commissioned (Mutschlechner, 1979). Furthermore, Robert Helmreich (1983, p. 447), a psychologist who participated in many of these studies, has stated that "there is no available evidence. . .that these research programs have had any influence on the conduct of past operations or the organization and planning of future missions."

Social scientists have been tempted to explain this state of affairs by saying that engineers do not understand them, or that astronauts feel threatened by social scientists because of their experience with psychologists and the latter's role in selection for and de-selection from the program. However, those on the technical and operational side can just as easily accuse the social scientists of being trivial in their research and incomprehensible in their publications. While not denying that there may be real problems here of communication among sub-cultures, the time may now be ripe for a renewal of social science research on space living. During the 1970s NASA was forced to shelve its expansive plans and restrict its horizons. Social scientists wanting to talk about long duration missions had no audience. Now, however, the agency is being encouraged to develop a space station and to think ahead about returning to the Moon, as well as other visionary projects. My plea is that research and development on appropriate social systems be part of that forward-looking effort.

However, if given the green light to go ahead, don't expect the social science community to immediately bring forth a unified and empirically validated program. Just as the prospect of mining and processing lunar materials has resulted in a wide variety of proposals, so, too, would the prospect of social science research on lunar living elicit a wealth of ideas, models, and methodologies. My own viewpoint on the subject is derived from experience as an anthropologist working with small groups, including those involved in maritime exploration. Let me briefly outline four points that would be important to a social science research and development program.

First, don't separate social science from everything else. As Miller (1984) points out, we are dealing with living systems that are at once biological and social. And, of course, they are technological as well for they will not exist on the Moon without all the hardware and procedures for getting people there, housing them, and keeping them alive. Social scientists must work closely with biologists, human factors specialists, architects, and ultimately, the engineers and managers who conceive, design, and operate the whole system.

Second, make the planning of an appropriate lunar social system part of a larger, iterative program for learning how to live in space, whether in orbit, on the surface of the Moon, or on some other body. This program should build upon previous experiences—in space and in analogous situations on Earth. It should focus intensively now on the space station, then apply the lessons from the space station to the lunar base, then learn from the first lunar communities, and so on.

Third, conduct realistic simulations of space social systems before they are put into operation. While it may be far too early to start simulating lunar communities, soon we should have enough design information to start space station simulations.

Utilizing realistic mock-ups of a space station, experiments could be conducted to investigate various hypotheses on crew composition and structure. For example, do one simulation with a crew organized along hierarchial lines with a commander in complete control, as a captain on a ship, and then do another simulation in which authority is shared according to specified roles and responsibilities. Test various personnel combinations—female/male ratios, proportion of scientists to traditional astronauts, and so forth. Investigate optimum crew size and rotation systems by actually trying them out. From such simulation experiments and from other research and experience, an appropriate space station social organization could be designed, then tested in space and modified according to experience.

By the time the space station is operational, plans for a lunar base may have advanced to the point whereby a lunar community could be simulated. Using findings from the space station simulations, and then actual operations, it would be possible to refine models for long-duration space living, tailor them for the special conditions of lunar living, and then test them with simulations.

Simulation experiments should use realistic mock-ups for the space station, lunar base, or whatever the relevant system under investigation. They should be conducted for long periods equal to, or at least approaching, the length of the projected missions. And the participants should be given real scientific, materials-processing and maintenance tasks to perform throughout the duration of the simulation.

Such an ambitious project would be expensive and difficult to undertake. But if it could isolate factors critical for space living and thereby help lead to the design of social systems for space that would enhance safety and productivity, such a simulation program would repay the investment.

Fourth, include self-design by those who will actually live in space. Make them active participants in the research and development of the social systems in which they will live, instead of passive and perhaps alienated subjects of experiments and plans developed solely by others. This last point raises the issue of lunar community autonomy. Although a lunar base might start out being totally, or almost totally, dependent on Earth for materials and supplies of fuel, food, oxygen and other vital items, the ideal would be to develop progressively greater degrees of self-sufficiency. Greater material self-sufficiency implies increasing social self-sufficiency ranging, for example, from local initiative in research to self-governance of the community itself. Such close supervision from Earth as is involved in day-to-day scheduling by mission control, or in the step-by-step direction of experiments by ground-based principal investigators will have to give way to some measure of lunar base autonomy—if the benefits of adapting to this new environment are truly to be realized.

This trend toward autonomy should be anticipated, not ignored or resisted. If we really want to learn how to live in space, the locus of creativity must someday shift from Earth to space. As lunar communities grow in size and competence, so they should be encouraged to develop their own solutions to the problems of living in space. In so doing they would be developing the first of many space-based cultures that could enhance humanity's future.

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LESSONS FROM THE PAST: TOWARD A LONG-TERM SPACE POLICY

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Space is a new environment, but there are examples of past human migrations that can provide valuable lessons to settlement planners. The colonization of the isolated, resource-poor, and previously uninhabited island of Barbados in the early 17th century reveals the weaknesses of corporate-sponsored settlement. The Antarctican experience of the late 1950s, on the other hand, underscores problems with government-organized projects. The unique requirements of space exploration and development in the long term call for a hybrid of these institutions—corporations and government. Combining the best of both may be a wise space policy objective.

INTRODUCTION

The exploration and development of space promises both economic benefits and advances in scientific knowledge. Now with the lure of potential new products and services, industry is beginning to speculate about new medicines, alloys, and crystals that could be produced in orbit. Space scientists, engineers, and even sociologists recognize that a whole array of new products and new fields of knowledge await discovery.

The central space policy question today is what system will direct this growth. Until recently, space exploration and development has been a government operation. Now, with the lure of potential new products and services, industry is taking a more direct role in space enterprises. The legal, financial, and political barriers to commercial space development will not disappear in the near future, but they do not appear to be insurmountable hurdles. Yet it is unlikely that the organizations that spawned space exploration, national governments, will simply fade out of the picture. It is not yet certain what system—governmental, corporate, or some new combination—will prevail in space in the coming decades.

Pertinent lessons from past migrations can help us clarify the uncertain future of space development. Historical analogies obviously have their limits; nevertheless, they are our only guides to the future. By examining past colonization attempts, we can make more informed decisions on what system may, and should, work best in space.

Only governments and corporations can afford the enormous capital investments required for extensive space exploration and development. This is the starting point in our search for relevant historical analogies. Other key factors include the absence of native peoples in orbit or on the Moon, the radically different environment, and the need to supply even bare essentials, especially in the early years, in order for human settlers to survive. Our search, then, is for settlement attempts that developed under similar conditions, but under different institutions.

BARBADOS

Planting countries is like the planting of woods; for you must make account to leese almost twenty years profit, and expect your recompense in the end. For the principal thing that hath been the destruction of most plantations, hath been the base and hasty drawings of profit in the first years. It is true, speedy profit is not to be neglected, as far as may stand with the food of the plantation, but no further.

—Francis Bacon, 1597 (Miller, 1983, p. 81)

The colonization of the West Indian island of Barbados by a group of merchants is a fascinating story of corporate colonization. This resource-poor, uninhabited, and subtropical island rivaled early Virginia in population and wealth, though endowed with only a fraction of the land. The boom was short-lived. Within two decades of its founding, Barbados was locked into economic specialization and dependence that still cripples it today. Assuming that space development might also hinge largely on corporate involvement and the potential for great economic profit, 17th-century Barbados could provide the late 20th Century with some valuable lessons.

The attempt to settle this small and isolated island began in London in the early seventeenth century. The survival of the Virginia colony, organized and financed by London merchants, was in serious doubt until settlers began to earn a profit from tobacco. The market for the leaf grew rapidly and attracted other London entrepreneurs. One wealthy merchant, William Courteen (originally a Dutchman), organized a syndicate that he hoped would reap profits from the new product. He raised £10,000 and secured a royal patent to the island of Barbados.

The Courteen Syndicate sent a ship in 1627 to settle and develop the island, which is isolated from neighboring isles by the prevailing easterlies. Today we know that Amerindians once inhabited Barbados prior to the European settlement, but the leader of the expedition concluded that there were "noe people on the island untill they [the English] came" (Harlow, 1926, p. 40). "Wild pigs ran free, but there were no staples such as corn, and no cleared land" (Bridenbaugh and Bridenbaugh, 1972, p. 63). There was not even a large supply of fresh water. One early settler complained that on Barbados, "water is to be prized above any thing else" (Bridenbaugh and Bridenbaugh, 1972, p. 63).

The expedition was forced to divert to the Spanish Main to trade with natives "for all things to be gotten for the planting of this island Barbadoes" (Harlow, 1925, p. 40). A small number of Arawaks, the indigenous people, asked to be taken along by the British, and they were granted a plot of land on Barbados. Within a matter of a few years, however, all were enslaved and soon died, and their important knowledge of the environment was lost.

The island was out of the range of the aggressive Carib (from whom we get our modern word cannibal). The Carib were a threat to Arawak and European peoples well into the 1700s, but Barbados was the sole island in the Caribbean that was secure from their raids (Bridenbaugh and Bridenbaugh, 1972, p. 63). Unlike contemporary Virginia and New England, the Amerindians played a minimal role on Barbados.

The Courteen Syndicate, though founded in a capitalistic spirit, was not an innovative organization. The colonists were hired hands expected to grow tobacco in order to pay off the original investment of the merchants. As the historian Harlow reports, the settlers were more serfs than pioneers. "Neither the land nor the stock," he writes, "were their own; they were merely his [Courteen's] tenants at will, working the demesne of the lord of the manner" (Harlow, 1926, p. 7). The London merchants wanted to pay back their investments and make a profit; they did not link monetary gain with a healthy, well-adjusted settlement.

Most of the settlers were young, single men who came not to settle but to earn a wage and perhaps have some adventure. They cared little for the ecological health of the land, living facilities, a nutritious diet, sanitation, or their neighbors. Early on, writes one historian, "feud and faction became the order of the day in a little community faced by perils enough" (Harlow, 1926, p. 12).

Introduction of private land ownership in 1630 did not greatly alter the settlers' way of life. The economy remained totally focused on tobacco. But the tobacco grown on Barbados proved "very ill-conditioned, fowle, full of stalkes, and evil-coloured" (Bridenbaugh, 1968, p. 53). The product could not compete with the superior Virginia leaf. There was little profit to be made, but the colonists continued to shun subsistence foods, remaining dependent on imported food and drink and the island's wild pigs. One visitor predicted in 1631 that "this plentiful world of theirs is now passed" (Harlow, 1926, p. 24). The starving time of 1632-1633 followed.

Tobacco was gradually abandoned, and a new crop, cotton, became Barbadian gold. But it was only with the introduction of sugar in the 1640s that substantial wealth began to flow into Barbados. "Curiously enough," notes one historian, "this access to prosperity, advantageous as it was from an economic point of view, eventually proved to be the main cause of the island's decline" (Harlow, 1926, p. 43). This is not difficult to explain. Anyone with enough land or capital became, in the words of one contemporary, "so intent upon planting sugar that they had rather buy foode at very dear rates than produce it by labour, so infinite is the profitt of the sugar workes once accomplished" (Dunn, 1972, p. 53). Initial investments for sugar works were too high for the vast majority of settlers, and the larger landowners began to buy up the small farms. Slaves were brought from Africa to work these vast estates. Barbados became locked into an economic specialization that, however profitable in the short-term, was disastrous for the overall health of the island. It has never fully recovered.

A lack of control by the island government, the transient population, and the incredible concentration of people (in the 1640s Barbados had one of the densest populations in the European world) resulted in appalling living conditions, even for the period. Open sewers and polluted drinking water spread epidemics; mortality in 1647 reached such horrible proportions that in the main village of Bridgetown, they threw the dead directly into the river "so that many died in a few hours, poisoned by the drinking water" (Southey, 1827, p. 315).

Alcohol was available but expensive. Drinking was nevertheless the favorite pastime for the young men, who were thousands of miles and several months away from home. "If ye would but bridle ye excesse of drinkinge," wrote one despairing visitor to the islanders, "together with ye quarrelsom conditions," then, he believed, there might be some semblance of stability (Harlow, 1926, p. 66).

Early Barbados presents us with the disturbing picture of a chaotic settlement with a weak government, a vulnerable economy, and colonists who refused to adapt to new conditions. This last point is particularly important. Spanish settlers appear to have more readily adapted their agriculture, architecture, and clothing to the New World. On Barbados, by contrast, one visitor found wealthy plantation owners living in "timber houses, with low roofs, so low for the most part of them that I could not stand upright with my hat on" (Bridenbaugh, 1968, p. 39). When the visitor proposed to design an innovative house that would take account of the trade winds, pests, and the late afternoon sun, even the most educated "did not or would not understand" (Bridenbaugh, 1968, p. 34). The English simply could not adapt quickly enough to an environment far more alien to them than to settlers from Mediterranean regions.

The "gold rush" or "every-man-for-himself" economy undermined attempts to deal with problems in a systematic way. Unlike their Spanish contemporaries in the New World, the English did not plan towns, build public sanitation systems, or enforce strict laws. The cooperation needed to accomplish these things simply did not exist among settlers who, as a visiting Frenchman wrote, "all came in order to make money" (Bridenbaugh and Bridenbaugh, 1972, p. 35).

Based on the experience of Barbados, space development should avoid the pitfalls of economic specialization. A colony self-sufficient in basic needs with a diverse export product line would be more stable than a settlement largely dependent on the outside world, where forces are often beyond its control. In addition, a diverse population—including men, women, and children—would add permanence to a settlement.

The success (in both human and monetary terms) of a colony is dependent on strong coordination among the settlers, cultural flexibility, and the subordination of short-term gains for long-term returns. This latter may prove difficult for an industry eager to pay back nervous investors. A purely corporate development of space could follow some of the paths of the Barbadian settlement. Companies might be tempted to skimp on infrastructure (such as expensive redundant systems). Such cost-cutting could have catastrophic effects. Industry could also tie the economy to a single profitable service or good. If this occurs, price fluctuations on the international market could doom the colony's long-term growth.

Should the path of space development therefore be blazed by government? Let us examine an attempt by a national government to settle an uninhabited, remote, and resource-poor area.

ANTARCTICA

It is easier to escape the omnipresence of people in New York than in Antarctica.
—Ernst Stuhlinger (1969, p. 6)

The early years of settlement in the Antarctic provide an example of a government-sponsored project clearly analogous to the first steps we are making in space. The continent has no indigenous peoples, the production of the most basic essentials (such as water) requires great effort, and it is unlike any other environment on Earth.

Antarctica has been permanently settled only since 1954. During the International Geophysical Year (IGY) 1957–1958, a dozen nations joined together to build scientific stations on the continent. Planning the logistics of supplies, transportation, and coordination of the IGY was an enormous task. "Men and equipment had to be shipped in a scale hitherto undreamed of" (King, 1969, p. 241). The American project was the most ambitious, and the Navy was placed in charge of logistics. Five scientific bases were to be ready by early 1957, complete with two years' worth of supplies. Everything had to be imported, and the nearest airfields were thousands of kilometers away in New Zealand.

Erection of the South Pole station was particularly difficult. The pole is 1300 kilometers from the main base at McMurdo Sound. Located high on the Antarctic Plateau, the windiest, coldest, and driest desert in the world, the sole natives of the pole are a few colonies of microbes.

All parts of the base were specifically designed to fit the cargo bay of C-124s. The sections of the structure could then be dropped from the air. By the onset of the winter, Seabees (the Navy's construction battalion) finished the cluster of Jamesway huts. Connected by short passageways and equipped with a galley, radio room, bunkrooms, and ample storage space, the new base was luxurious compared to the past dwellings on the continent. But Paul Siple, a close friend of Admiral Byrd and one of the last of the original Antarctic explorers, watched in sadness as "these young titans of modern Antarctica threw together a series of Jamesway huts surrounded by a ring of litter that made the glamorous pole look like the corner of a city dump" (Lewis, 1965, p. 22).

Siple was appalled by the waste and poor work done by those "accustomed to the opulence of the military service" with an attitude of "get the job done and to hell with conserving supplies" (Lewis, 1965, p. 72). Siple understood that this attitude had no place in an environment that demanded efficiency, careful planning, and respect.

Inside the base there were no private rooms; the latrine was distant, and the temperature varied from 0°C on the floor to 40°C at the ceiling. The man with the bottom bunk froze while the man on the top sweated. Many work sites had no connecting passageways and could only be reached through the outside. Food was good and plentiful, but the diesel generators made an earsplitting racket that never ceased.

Water was particularly hard to supply. The pole station reported during one winter "twice a week over five tons of snow must be dug by hand for the snow melter in temperatures of -90°F and winds 20 mph—all at an altitude of 10,000 feet above sea level" (Lewis, 1965, p. 276). Despite this effort, the water continually tasted of the diesel fuel used to melt it.

The design, though revolutionary, lacked any cohesive plan. No private architects were consulted, no psychiatrists were asked for suggestions, and no construction firms offered alternative designs. Time constraints and the bureaucratic structure of the Navy precluded a more flexible approach. Within a few seasons the entire base at the South Pole was covered by blowing snow.

The permanent bases were a major departure from past exploration. After wintering over in 1958-1959, C. S. Mullin believed that "danger, hardship, or the direct effects of the cold did not represent important stresses" (Mullin, 1960, p. 322). The psychosocial environment assumed importance very quickly on the bases. During the first winter, one of the 18 men in the party developed "a frank and florid psychosis" (Nardini *et al.*, 1972, p. 97). There was, of course, no way to evacuate him, and there were "no provisions for adequately separating such a patient from the remainder of the group" (Nardini *et al.*, 1972, p. 97).

Selection procedures were subsequently tightened and proved fairly successful. But a deeper problem revolved around the organizational structure of the smaller Antarctican bases. In one case, overworked support staff began to question the right of scientists to avoid housekeeping duties. No open hostilities broke out, but the problem was "a cause of serious dissension and disruption in the group" and, more ominously, "the situation was never resolved" (Lewis, 1965, p. 273).

A winter base in Antarctica is a unique world, where the cook often has greater prestige than the officer-in-charge and the radio operator can have more influence than an accomplished scientist. The traditional hierarchical structure of the military, and of government as a whole, breaks down among a small group of people isolated from others for months at a time. This was a controversial and embarrassing realization for the Navy. Flexible authority and sharing of tasks among everyone are vital for the well-being of a small, isolated group. This can run against the grain of highly specialized scientists and career military officers. The absence of women was also a factor. Navy traditions excluded females from the continent, and this increased tensions.

Government sponsorship of operations in Antarctica during the late 1950s did not result in any attempts to develop self-sufficiency. The Navy made no moves to develop the native resources to lower the enormous costs of transportation. Windpower was just one of many alternative energy sources that were never tapped, and greenhouses to produce fresh vegetables might have had additional psychological benefits (the Soviets grew plants at an early stage in Antarctica, and now aboard the Salyut space station as well, B. J. Bluth, personal communication, 1984). A huge armada of ships and planes continues to supply the bases in Antarctica every year with energy and food.

Some lessons have been learned. With great reluctance, the Navy eventually allowed women on the continent, and a new base on the South Pole includes a geodesic dome that prevents snow build-up. A more flexible organizational structure is tolerated, and private enterprise is now providing some services and personnel. But the early years of inefficiency, poor design and construction, and inappropriate organization could be repeated if government plans long-term space development on a large scale.

The Antarctican experience reminds us that the danger of mutiny or psychosis in a space station or colony are as real as the threat of meteors or solar flares. The importance of the psychosocial environment in space development must not be underestimated. Not only crew selection, but station design and the organizational structure play a large role in the stability of a small group. Task generalization can defuse tensions; flexible authority is vital; and mixing sexes appears desirable. The past tendency of high-tech planners to ignore psychosocial considerations must be curbed as we enter space. These considerations can often be accommodated without undue difficulty. Self-sufficiency in basic needs, for example, can bring down costs (economic benefits) and also provide a hobby for settlers (psychological benefits).

Basing a space policy purely on scientific research, as is the case in Antarctica, is probably not an optimal choice. The rise and fall of NASA's budget over the past two decades underscores the difficulty that the scientific community has in controlling its own destiny. In times of fiscal restraint, those projects with the least public support are often the first cut, and research is often a prime target. An emphasis on pure research in space heavily ties policy to the political winds on Earth and slows the chances for steady growth.

Handing the reins of space development to the military might be just as unwise. Budgets would still depend on political considerations on Earth. The military of both superpowers already are changing their emphasis in space from surveillance to weapons. A scenario of space containing sophisticated weapons systems controlled by bureaucratic organizations and produced by classified research is not a very appealing vision. Industry would, of course, gain short-term profits. But a healthy and viable economy would be very unlikely to ever develop in a largely military scenario.

An essentially profit-oriented approach to space policy might, however, have similar disadvantages. A corporation, eager to pay back initial investments, could insist that settlements concentrate on the production of one or a few profitable products for export. Should a cheaper substitute or process be discovered that could produce the goods or services on Earth, space development could come to a halt. The space inhabitants might find themselves as dependent on the economic winds of Earth as their counterparts in the government-controlled scenario are tied to politics.

CONCLUSIONS

As we have seen, both a largely corporate and a predominantly governmental approach to space development have their respective dangers. Industry might be unable to wait patiently while settlements struggle through their early, most vulnerable, years. Government, on the other hand, could delay development through costly and inefficient management techniques.

A vision of large, permanently inhabited colonies in space should include highly self-sufficient settlements that produce a wide variety of goods and services. This future scenario should also include a tolerant organizational superstructure that would require an economic return from the colonies, yet be cautious not to demand too much too soon.

A successful long-term space policy cannot be built upon cries for free enterprise, nor can it rest on traditional central planning. A hybrid of institutions and ideologies could best overcome the deficiencies inherent in both systems. Both COMSAT and INTELSAT are beginnings. And Ariane is already influencing the policies of traditionally bureaucratic NASA, as well as the small private launch companies.

Government/corporate cooperation in space development is not just a passing accommodation. The unique physical, economic, and political conditions of space require a fresh look at our current institutions and ideologies. We owe it to future generations to choose a long-term policy that will ensure survival, health, and prosperity in space.

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HISTORICAL PERSPECTIVES ON THE MOON BASE—COOK AND AUSTRALIA

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Among the many historical episodes that have relevance to the establishment of a lunar base, the voyages of Captain Cook and the founding of Britain's Botany Bay colony in Australia seem particularly appropriate. The process resulting in the selection of Cook rewards study, as do his relations with the Admiralty, with the scientific establishment, and with the scientists who accompanied him. Britain's tight control of the Botany Bay settlement and its unwillingness to promote early self-sufficiency may have delayed the time when Australia became self-supporting. Structuring the lunar base to offer opportunities for private initiatives may hasten the day when it becomes a self-supporting settlement rather than an externally supported scientific base on an Antarctic model.

Learning to live and work in space is going to require some adaptation. However, we should remember that, in the words of historian Alfred Crosby (1985), "We have done all this launching out into space before." During the five million or so years that the hominid line has been on this planet, our ancestors have constantly probed the limits of human capabilities, learning through the development and use of culture and technology to live in environments for which they were not physically adapted.

The coming era of space development has many parallels in the past: the spread of hunting and gathering peoples across the face of the planet, the oceanic exploits of the Polynesians and the Vikings, the flowering of Greek culture around the Mediterranean during the classical period, and the stillborn Chinese maritime initiative of the early Ming Dynasty. Each of these, along with the later explosion of European mariners into the World Ocean, have lessons to teach us, providing both inspiration and caution. This essay highlights two related but distinct episodes from the British experience. These examples illustrate the interplay between individuals and institutions, between goals and means.

Captain Cook

In 1768, Britain was the superpower of the day. The long war with France in Canada was drawing to a close following the fall of Quebec. Tensions were beginning to build with the American colonies and would soon lead to revolution. Meanwhile, another sort of revolution, this one in industry, was altering the fabric of British society. Britain was beginning to dominate world commerce and the seas that were making global trade possible. However, in those middle decades of the eighteenth century, despite the fact that Europeans had been sailing the Pacific for nearly two centuries, much of that vast ocean was still uncharted owing to the fact that navigation still relied on dead reckoning and latitude sailing. The problem of determining longitude was unsolved, and, as a consequence, much of the map of the world was blank or filled with lands that were more fantasy than reality, particularly in the southern Pacific. However, in his three voyages James Cook would replace the mapmakers' fantasies with a known ocean and would make global voyages safer and more certain (Beaglehole, 1974).

A primary motivation for Cook's first voyage was scientific. One of the central problems of the day was that of astronomical distances. In 1767, the Royal Society urged His Majesty's government to send a party into the Pacific to observe the Transit of Venus. The government was persuaded, but the Lords of the Admiralty were looking beyond the narrow scientific question and seeing an opportunity to address more practical problems. Was there a southern, temperate continent in the south Pacific where Britain might profit? What resources and shelter were there in the Pacific to support British interests? And would the newly published Nautical Almanac bring longitudinal calculations within the reach of non-scientists? Consequently, the Admiralty wanted their own man as leader of the expedition; they chose not from the scientific establishment but from naval ranks.

They chose for skill rather than rank, plucking James Cook from North American service where he had been charting the coast of Newfoundland. Cook succeeded beyond all expectations, removing the mythical southern continent from the maps, adding the east coast of Australia, accurately plotting the positions of the far-flung islands of Polynesia, and correctly surmising the existence of Antarctica. He also proved the worth of the almanac and, during the second voyage, of the new timepieces with which the problem of determining longitude was solved. In the bargain he defeated scurvy and gave Europe detailed knowledge of the peoples and products of the Pacific. Perhaps the greatest tribute came from Benjamin Franklin, who in 1778, despite the fact that Britain and America were then at war, urged that ships in American service "treat the said Captain Cook and his people with all Civility and Kindness, affording them, as common Friends to Mankind, all Assistance in your Power."

Yet, however much the Cook saga may provide inspiration for those who would explore the ocean of space, it should also provide some cautions. Obviously, a man of Cook's talents was the right choice to command the voyages, rather than an astronomer or a certain geographer the scientific establishment had proposed. A practical seaman, an accomplished navigator, and a leader of men was needed for the three-year circumnavigation—not a scientist.

But Cook did make mistakes, particularly on the third voyage. By then he had become tired and was probably chronically ill as well. What is more, this bright star of the Royal Navy, who had already done so much to advance knowledge, had become so alienated from scientists, particularly as a result of episodes connected with the second voyage, that he would have none aboard his ships. So an exhausted Cook, without equals to advise or perhaps restrain him, sailed to his doom; he was killed in Hawaii, the victim of one of his own rare lapses in judgment.

In any undertaking of this kind there is conflict between the need for autonomy on the one hand and advice and supervision on the other. In Cook's time autonomy was a necessity; he was literally out of reach for years at a time. The Admiralty chose a man who had inspired the confidence of Hugh Palliser and other high-ranking officers with whom he had served in Canada, gave him broad instructions, and hoped for the best. Their trust was rewarded, although it is tempting to second guess and wish that Cook had had ranking advisors on the fatal voyage.

Autonomy on the scale that Cook experienced is no longer possible, necessary, or even desirable. The definite advantage to rapid communication is that experts can be called on to supplement the skills and judgment of the flight crew. However, as both we and the Russians have relearned in recent years, flight crews sometimes resent what they consider to be too-frequent interference from the ground. But, we do seem to be learning; at the close of a recent shuttle mission, ground personnel were complimented on their helpfulness and their willingness to accept the flight crew's judgment.

These recent examples and the Cook experience suggest that the best course of action is to choose the most qualified people and, as long as they are getting the job done, to offer advice and instructions only when absolutely necessary or when requested. On occasion Cook could have used a senior advisor, as he had during the first voyage in the person of Joseph Banks (later President of the Royal Society). But Cook's great success probably came because he had freedom to exercise his considerable talent and judgment. There is a middle ground, but it is probably best to err on the side of autonomy. We need to be reminded of that from time to time.

Australia

Cook's discovery of Australia's east coast led to the establishment in 1788 of a British colony (Blainey, 1968; Shaw, 1972). Botany Bay started out as a penal settlement. The American Revolution had created a crisis for the British penal system; convicts from the slums of the growing cities were no longer welcome in the Americas. In 1784 James Matra, who had sailed with Cook, promoted the idea of an Australian settlement, although as a haven for American loyalists and as a theatre for new commercial ventures. The government was not much interested in the commercial possibilities but was willing to entertain the idea, soon championed by Banks and by the Home Secretary, Lord Sydney, of a penal colony. Access to flax and timbers from tiny Norfolk Island may have been the principal attraction (Blainey, 1968).

As originally conceived, the settlement was soon to become self-sufficient, thanks both to the rich soil Banks described and to the toil of convicts. Unfortunately, it did not work out that way. When Captain Phillip arrived at Botany Bay in 1788 with a party of over 1000 people, he discovered that the soil was not at all suitable and that few of the over 700 convicts had any useful skills. By 1790 Phillip was writing to London: "The sending out of the disordered and helpless clears the gaols and may ease the parishes from which they are sent; but, Sir, it is obvious that this settlement, instead of being a Colony which is to support itself, will, if the practise is continued, remain a burden to the mother country." What Phillip desperately needed were people with the appropriate skill and with an interest in the future of the settlement. London balked, however, at the idea of granting land to convicts who had finished their sentences. The thought did not square with the perceived need for punishment. Would not news of their success incite further waves of crime in the cities? To add to their problem, Norfolk Island proved to make poor sail cloth, while the lack of good landing places on the island made it almost impossible to off-load the tall pine trunks needed for ships' masts.

Despite these setbacks, support for the colony continued. London realized that Australia's geographic position along the routes to Asia was of strategic importance. Not surprisingly, London was preoccupied with the coast, and it was decades before local interests began to turn inland.

Local interests did develop. Because there were few free settlers in the early years, the initial impetus came from the private interests of the military. Officers in the New South Wales Corps were, like their counterparts throughout the British Empire, often younger sons blocked from family wealth and titles by elder brothers. They had come to Australia to make their fortunes. A group of them, including the notorious John MacArthur, gained virtual control of the economy, buying grain cheaply in years of abundance and selling it dearly in the frequent years of devastating drought. In 1806, Governor Bligh tried to undermine the speculators, buying wheat at a fair price in a year of plenty and distributing meat from government supplies to farmers devastated by floods. MacArthur and his friends were not to be denied, however; they rebelled and eventually, through the aide of powerful friends in London, had Bligh recalled.

MacArthur and people like him had positive roles to play as well. They introduced sheep and, with their accumulated wealth, acquired the large tracts of land needed to support flocks in the poor climate. Wool was the first step toward self-sufficiency, the first exportable product of the settlement. Only wool was valuable enough that it could bear the cost of internal transportation in a land lacking navigable rivers, as well as the cost of shipment to Europe, and still yield a profit.

But who was to get land and at what price? Would convicts continue to work for private individuals and, in a kind of work-release program, be able to work for themselves part of the time? How would free settlers be encouraged to come? And how much control would the colonists be permitted to take of their own political destinies?

It would be decades before these issues were even partially sorted out. Transportation of convicts to the built-up areas of New South Wales ended in the 1840s. The discovery of gold brought a flood of new settlers in the 1850s, who then had to be absorbed into the mainstream of the settlement as the gold ran out. Despite the lure of the great expanses of open land, Australians learned slowly that much of their continent was not made for farmers; the lack of rivers and the natural link between farmer and market made it cheaper to feed Australia with Indian grain before the coming of the railroads. For this reason Australia has been an urban nation from the very beginning, largely confined to a narrow strip of fertile coast in the south and east.

Most of the problems of the early decades arose because Australia was a very different place than many had believed in the beginning. Although there are some parallels with the American experience, Australia presented some unique problems. Australia was very far from England, and, as the first parties discovered, a continent less blessed with Nature's bounty than supporters of the settlement had led the government to believe. It was a dry land, subject to frequent drought, and British crops did poorly. So, too, did the convicts who were cast into this new land without basic survival skills. And, for the first few decades, there were few free settlers; potential immigrants were kept away by distance, a lack of opportunity, and official policy that discouraged their coming before around 1820. But free settlers did come. They and the convicts who had served out their terms found ways to make livings and gradually to build a self-supporting community. All that happened in less than a lifetime, and by 1840 Australia was, for practical purposes, standing on its own feet.

What does the Australian experience have to teach us, as we contemplate a return to the Moon? Australia is not the Moon; it is a terrestrial environment far more benign than our airless satellite, but there are similarities. In broad brush a few pertinent features stand out. Living on the Moon is going to be a new and initially difficult experience. The lunar base will start small and be very dependent on Earth. The first "settlers" will have to be technically trained: astronauts, engineers, and scientists. Bureaucracies will oversee the operation from afar; administrative control will be and must be tight. The costs and difficulties of transportation will in large measure determine the pace of settlement and the products that can be profitably produced.

If the lunar settlement is to grow and eventually become self-supporting, some helpful features can be built into this social experiment from the beginning.

First, the stated purpose of the lunar base must be the eventual establishment of a self-supporting lunar settlement. If that purpose is clear from the beginning, then the inevitable transition from a tightly administered scientific base to a more open community may come more easily. If, on the other hand, we say that we are going for purely technical reasons, then the interests of entrepreneurs and private settlers (on whom ultimate success may well depend) might not receive proper attention.

Second, reducing the cost of transportation must be a main concern, although we anticipate that these costs will remain high for a period of time. During that initial stage subsidies of public and private ventures will be required.

Third, there should be emphasis on the development and encouragement of profitable enterprises through technology transfer, tax incentives, and the development and maintenance of basic services.

Fourth, there should be mechanisms established for the orderly transfer of control of lunar operations to the settlers as the population grows—mechanisms analogous to the Ordinance of 1787 in the United States and those used by Britain to create independent nations such as Australia, New Zealand, and Canada.

There will be conflicting interests, shifting purposes, short-sightedness, greed, and mistakes. The lunar base is going to be expensive and will remain so for longer than some of us would like. If we give careful thought to the design of the experiment now, however, considering the human as well as the technical aspects, and keep our eyes open both for the pitfalls and the opportunities that will come along later, perhaps self-sufficiency of the lunar settlement will come quickly.

Finally, we should remember that Britain supported the Australian settlement long enough for it to succeed. Let us hope that we can do the same for the lunar enterprise.

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SPACE POEMS: CLOSE ENCOUNTERS BETWEEN THE LYRIC IMAGINATION AND 25 YEARS OF NASA SPACE EXPLORATION

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The National Aeronautics and Space Administration was created in 1958, after the uproar in 1957 over Sputnik, Russia's (and the world's) first Earth-orbiting satellite. NASA is a federal agency charged with carrying out government policies in specific areas for research and development in science, engineering, and technology. Unlike many government efforts, NASA has generated activities and images with wide appeal to millions of people, not only in America, but around the world. The space program and people's responses to it are phenomena unique to our time; living in our time necessarily includes coming to terms with the fact that the human species is actually moving off the planet. From the beginning of the program, many people longed for an eloquent communication from spacefarers, something more than "Everything is A-OK—the view is really great up here!" Among the grumblings, the idea surfaced early that NASA ought to send a poet into space. The agency had other priorities, although it now has a valuable collection of paintings and drawings by artists who were invited to monitor its activities. An "Arts in Space" program is now in the long-range planning stage to send poets, painters, sculptors, composers, dancers, and other creative artists to the proposed Space Station to work for several weeks at their respective expressive arts. Meanwhile, American poets have been on Earth; how did they respond to more than 25 years of space exploration? This question can be answered by a survey of the patterns of space imagery the poets selected for literary representation in their work, and their attitudes toward it.

In the anthology *Inside Outer Space* (Vas Dias, 1970, p. 141), we find poet Robert Kelly saying, "What we have needed / is a language / always needed a tongue / to caress our technology." This means being more creative with the language we have inherited, learning to adjust both it and ourselves to the new world revealed to us by science and transformed before our very eyes by technology. Only thus can we live in the present and be late 20th Century poets. This challenge is no different in kind from that explained by Hart Crane (1966, pp. 261-263) in his essay "Modern Poetry" in 1929.

> *The function of poetry in a Machine Age is identical to its function in any other age; and its capacities for presenting the most complete synthesis of human values remain essentially immune from any of the so-called inroads of science . . .For unless poetry can absorb the machine, i.e., acclimatize it as naturally and casually*

> *as trees, cattle, galleons, castles and all other human associations of the past, then poetry has failed of its full contemporary function . . .Contrary to general prejudice, the wonderment experienced in watching nose dives is of less immediate creative promise to poetry than the familiar gesture of a motorist in the modest act of shifting gears. I mean to say that mere romantic speculation on the power and beauty of machinery keeps it at a continual remove; it cannot act creatively in our lives until, like the unconscious nervous response of our bodies, its connotations emanate from within—forming as spontaneous a terminology of poetic reference as the bucolic world of pasture, plow and barn.*

By 1985, in an America over 90% urbanized, many more Americans have seen computer terminals and digital watches, ultimately brought to you by your local space program, than have seen plows. Nevertheless, for space imagery to carry the convincing power of spontaneous expression arising unconsciously from the deepest self, the poet must be able to acknowledge that space is a place where human beings have lived and are going to live, and he or she must be able to imagine living there in full intensity of sensory perception, emotional response, and cognition and language. Some poets who have chosen to write using space imagery are still earthbound, and mightily resist the transition to interplanetary civilization. Some use space imagery only to talk about themselves; this is as legitimate as using anything else in the universe to do that, but these poems are not primarily concerned with the social process of adjusting to the migration into space, which is my concern in this paper.

This social process, seen in its literary representations, encompasses a wide range of emotions. Among them is a wry and cynical humor, as in John Ciardi's couplet "Dawn of the Space Age," where he quips: "First a monkey, then a man, / Just the way the world began" (Ciardi, 1962, p. 30). This alludes to the test flights of trained chimpanzees like Able, Baker, Enos, and Ham, who were blasted by rockets to unheard-of heights in cramped capsules jammed with electronics; they responded to the flashing signals almost as well as the astronauts did shortly thereafter. William Stafford (Vas Dias, 1970, p. 304), however, seems to have misgivings and anxiety about the evolution into space. In "Dog Asleep," he imagines that a sleeping dog, twitching its feet, is dreaming about Laika, the Russian dog who died on her space mission. He says we try to console ourselves with the words, "It's for the best, / and Laika volunteered—she wagged her tail." But then we twitch our feet. The dangers were real enough, and many of them were unknown; radiation was known. In "23rd Light Poem" (Vas Dias, 1970, p. 172), Jackson MacLow advises:

> *Let them carry freight in those ships,*
> *moon minerals scooped by machines*
> *resistant to the ruthless rays,*
> *not men or other sentient beings*
> *dear to the fathomless Buddha.*

Sean O'Meary (Marcus, 1975, p. 81) imagines the worst: "All that remains of Astronaut / Orbits the morbid moon / Satellite and skeleton / Together as one." However, when the first man actually did go into space and orbit the Earth, William Carlos Williams (Vas Dias, 1970, p. 355) reports that

> *Gagarin says, in ecstasy,*
> *he could have*
> *gone on forever*
>
> *he floated*
> *ate and sang,*

and that when he returned

> *to take his place*
> *among the rest of us . . .*
> *he felt*
> *as if he had*
> *been dancing.*

Around the time of the flight of Apollo 7, before we landed on the Moon or even orbited it, James Dickey (1968, p. 26) prophetically predicted the future of manned space exploration in his poem "A Poet Witnesses a Bold Mission":

> *In a sense they are all poets, expanders of*
> *consciousness beyond its known limits. Because of them,*
> *the death-cold and blazing craters of the moon will*
> *think with us, and the waterless oceans of Mars;*
> *the glowing fogs of Venus will say what they are.*
> *And those places will change us also. We have not*
> *lived them yet, and perhaps have no language*
> *adequate to them. But these men will find that, too,*
> *as they plunge with their fragile and full humanity,*
> *with their wives and children, with their gardens*
> *and grocery lists and head colds and ideas for poems . . .*

With the first lunar orbiter, our cameras—those extensions of our power of vision—got far enough away from Earth to give us our first real picture of it in its true context: infinite blackness. The new perspective was both physical and mental, and was brilliantly described in a metaphor of Richard Peck (1971, p. 86): "He turned toward earth no longer at his feet: agate in onyx." May Swenson (1978, p. 94), in "Orbiter 5 Shows How Earth Looks from the Moon," perceives the Indian Ocean as a woman in 3/4 profile, sitting on her heels with her bare feet tucked beneath the tip of Africa. The woman has a holy jug in her right hand;

Asia is
light swirling up out of her vessel . . .
Her tail of long hair is
the Arabian Peninsula.
A woman in the earth.
A man in the moon.

Ernest Sandeen, in "Views of our Sphere" (Vas Dias, 1970, p. 272), writes, "We deserved that earth-shot from the / moon's asbestos-gray horizon: a / family portrait on the old homestead . . ." He adds, "what can we hope for but smaller and smaller snapshots of this place?"

As for our only natural satellite itself, Arthur C. Clark (1969, p. 295) has cogently observed, "Although the Moon has inspired more verse than all the rest of the heavens put together, few poets have ever thought of it as a planet rather than a conveniently discreet source of illumination for their serenading." Among those poets who willfully refused to change their cultural bias, and who would have to be dragged kicking and screaming into the 21st Century, was the illustrious W. H. Auden. His poem "Moon Landing" (Phillips, 1974, pp. 162–163) reveals some of the worst "Bah! Humbug!" attitudes my research has yet encountered. "Unsmudged, thank God, my Moon still queens the Heavens," he writes, "as She ebbs and fulls, a Presence to glop at." Archibald MacLeish, in contrast, did not consider it "glopping" to write, in his poem "Voyage to the Moon" (Phillips, 1974, pp. 141–142), published on the front page of the *New York Times* on the day of the Moon landing:

Presence among us,
wanderer in our skies,
dazzle of silver in our leaves and on our
waters silver,
O silver evasion in our farthest thought—
"the visiting moon" . . ."the glimpses of the moon" . . .
and we have touched you!

He says of the Moon, "You were a wonder to us, unattainable," and he describes the three-day journey of the Apollo astronauts, who "steered by the farthest stars" through risk of death and "unfathomable emptiness" until they "set foot at dawn upon your beaches, sifted between our fingers your cold sand." Then comes the transformation: Earth replaces Luna as the celestial object overhead:

We stand here in the dusk, the cold, the silence . . .
and here, as at the first of time, we lift our heads.

Over us, more beautiful than the moon, a
moon, a wonder to us, unattainable . . .
Over us on these silent beaches the bright
earth,
    presence among us.

May Swenson (1978, p. 73) can imagine the same perspective: "All night it was day, you could say, / with cloud-cuddled earth in the zenith, / a ghost moon that swiveled."

Auden uses his poem to insult the rocket genius Wehrner von Braun, who was the software and the propulsive force behind the American space program, and also to assert the (alas! shortsighted) opinion that dying in the effort to colonize space, as several Americans and many Russians have already done, would have no meaning:

Worth going *to see? I can well believe it.*
Worth seeing? *Mneh! I once rode through a desert*
    and was not charmed: give me a watered
    lively garden, remote from blatherers

about the New, the von Brauns and their ilk, where
on August mornings I can count the morning
    glories, where to die has a meaning,
    and no engine can shift my perspective.

Auden's immovable perspective is deeply grounded in literary culture, myth, and legend. Lisel Mueller, too, understands that the Moon can never be the same again: "Goodbye crooked little man / huntress who sleeps alone / dear pastor, shepherd of stars . . .we trade you in as we traded / the evil eye for the virus . . .Scarface hello we've got you covered . . ." (Phillips, 1974, pp. 147–148). Mueller's sarcastic tone reveals that she is on Auden's side in this controversy. In his poem "Apollo: For the First Manned Moon Orbit," James Dickey (Vas Dias, 1970, pp. 63–64) also acknowledges that the Moon is a "smashed crust / of uncanny rock ash-glowing   alchemicalizing the sun / With peace: with the peace of a country / Bombed out by the universe." His poem recreates the astronaut's urgent longing

to complete the curve   to come back
singing with procedure . . .
And behold
The blue planet steeped in its dream
Of reality, its calculated vision shaking with
The only love.

The tone of Dickey's poem is 180 degrees from sarcasm. It recounts an ultimate adventure to a land wondrous strange: one without any human associations. The Apollo 8 astronauts are the first human beings to see the Moon as it really is: they come, says Dickey, "in the name of a new life." This tone of astonishment, of the wonder and joy of discovering "the magic ground of the dead new world," continues in a companion poem, "Apollo: The Moon Ground" (Vas Dias, 1970, pp. 65–66). The tough American voice is unmistakable. One Apollo 11 astronaut says to the other:

Buddy,
We have brought the gods. We know what it is to shine
Far off, with earth. We alone
Of all men, could take off
Our shoes and fly.

Their mission is to collect Moon rocks for scientific research into the true 4.5-billion-year history of the Sun-Earth-Moon system. He says,

The ground looms, and the secret
Of time is lying
Within amazing reach . . .
We leap slowly along it . . .
The Human Planet trembles in its black
Sky with what we do . . .
We are this world: we are
The only men . . .
We laugh,
with the beautiful craze
Of static. We bend, we pick up stones.

The astronauts have humanized the Moon merely by being on it. Culturally, they "are this world." Robert Kelly (Vas Dias, 1970, p. 141) also understood that what matters in this unprecedented situation is

that human
breath will shape
utterance on the unconscious moon
wake it
& us
from the bitter long dream of silence
by breath
of a man's body
by the weight of his weight
breath
breathed into the moon.

Al Purdy (Vas Dias, 1970, p. 242–243) advises the astronauts to complete the range of human emotion while they are there, to "let a handful of moondust run thru your hand /

and escape back to itself / for those others / the ghosts of grief and loss / walking beyond the Sea of Serenity."

The mental jolt required to permit a new planet to swim into our ken can be considerable. In the poem "July 20, 1969," Robert Vas Dias (1970, p. 338) describes the sense of disorientation he experienced on the day of the Moon landing:

All day commentators have been talking
of eras, generations, voyages, all
the extra-terrestrial wandering
of minds hooked
on distances, historic precedents
and the mechanism of escape
velocities / my ears float in
waves of coded engineering
data, lists of steps to program
lunar orbital insertion, and I see
them swim in the deadly anti-
atmosphere, laying out
experiments like picnic tables.
I am exhausted by the matter-of-fact
recital of the incredible
and I begin to doubt I
exist outside relay circuits
to moon and back. . .

David Ignatow (Vas Dias, 1970, p. 118) describes a similar sensation:

At dawn, as you look up from the pavement
to the sky, feeling without foothold,
a starry wall is moving steadily back.
What do you say to that, you whining rockets?

The threat, real or imagined, perceived by many writers seems to be that, in losing a sense of being solidly grounded on this Earth (presumably where we belong), we will lose a sure sense of our own identity—who we are. Lois Van Houton (unpublished work, 1985) asks

And what will become of us, suffixed
in space
like the hanged man of the Tarot deck?
Will we be lost to ourselves   how
will we compensate this grandeur of
earth   with most foreign cold?

Rosemary Joseph asks, if men ever walk on Mars and Venus, "will they still be men in the / image of Adam?" (Joseph, 1966). Peter Viereck (Pater, 1981, p. 419), in "Space-Wanderer's Homecoming," imagines one of our remote descendants, "after eight thousand years among the stars," feeling a sudden nostalgia for August and Earth's version of nature. He returns, looking for his horse and harp, and says, "Oh my people . . .My name is—. / Forgot it, I forgot it, the name 'man'."

It may be this sense of disorientation that makes some writers fiercely resist the change to the space age. Maxine Kumin (Phillips, 1974, p. 156), for instance, reacted to a very early lunar probe ("They had meant / merely to prick," she says) by imagining that "the moon was undone: had blown out, sky high." The tides cease, "dogs freeze in mid-howl, women wind their clocks," and lunatics suddenly become sane. She had prophesied this in a dream, and because it came true, she has not dreamed since. May Swenson (1978, p. 214) ends her poem, "Landing on the Moon" with the question, "Dare we land upon a dream?" In her essay "The Experience of Poetry in a Scientific Age" (Nemerov, 1966, pp. 150–151), however, she clarifies that "My moon is not in the sky, but within my psyche." She does say she thinks man will "eventually infiltrate the solar system, and go beyond," but it may cost an evolutionary transformation into "homo mechanicus." Swenson in fact was fascinated by the space program until we stopped sending up manned missions in the early 1970s. Few poets seem to understand the beauty and excitement of the unmanned missions—robot spacecraft like the Pioneers to Venus, Jupiter, and Saturn; Mariner and Viking to Mars; and the sophisticated Voyager missions, which have shown us Jupiter and Saturn in breathtaking detail. Voyager 2 is en route to Uranus and Neptune, and I can hardly wait until 1986 to see the photos. In the poem that I wrote about this, humanity as a species has already become "homo technologicus":

We were ready for this
before we believed it could be
possible—homo technologicus
sending his eyes and ears, by remote
control, over a billion
miles away, to the outer
planets, and all their planet-sized
moons. To see these worlds
for the first time.

Funding problems: "Hey Voyager,
we're gonna hafta
pull your plug."
Voyager: "Are you guys crazy?
I just sent you fabulous
pictures of Saturn! And I'm on course

for Uranus and Neptune, and you're gonna
NOT LISTEN?!?"

The data stream. Bit by bit,
the binary numbers transform
themselves into visions cold and
beautiful, or, like Io, bursting
with volcanoes. The sun but a bright
star, and fading all the time.
Radiation, survived
and measured—Jupiter's
magnetic tail a paper dragon
back in the lab.

I am one of very few poets to write about these extensions of human consciousness. Another among the few is Diane Ackerman, who wrote a book called *The Planets: A Cosmic Pastoral*. In her poem "Cape Canaveral" (Ackerman, 1976, p. 59) she saw the tremendous significance of the 1976 Viking probes, sent to look for life on Mars:

how we'd gathered
on these Floridian bogs
to affirm the sanctity of Life
(no matter how or where
it happens), and be drawn, like the obelisk we launch,
that much nearer the infinite.

Ben Belitt agrees: "It is time to reinvent life, / we say, smelling ammonia from Mars / in a photograph" (Taylor, 1974, p. 268). Robert Fitzgerald says, "I regret I shall not be around / to stand on Mars" (Wallace-Crabbe, 1980, p. 39). Ray Bradbury blesses our new home: "Old Mars, then be a hearth to us . . ." (Bradbury, 1982, p. 212). It will happen, perhaps within 20 or 30 years. The first step in this evolution was the first step on the Moon, which I regard as a greater evolutionary breakthrough than the first slither of whatever sea creature first finned its way onto terra firma, because that, at least, was on the same planet! When Neil Armstrong touched the lunar regolith, he said, "That's one small step for a man, one giant leap for mankind," and he was right. I have it on good authority from Thomas Paine, Administrator of NASA at the time, that Armstrong thought this up by himself and kept it a secret until the appropriate moment—just like a poet! In my poem "Apollo 11," I imagine Armstrong feeling, if not articulating, the following thoughts:

The powdery moondust has
just settled—disturbed for the first
time in 4½ billion years, by our

retrorocket. Only with these
electronic shells, this new carapace
we ourselves have made, can we
swim through the vacuum waves
to reach and touch this shore. The
waterplanet's salt surging through my
nerves, my hands tremble on the sturdy
ladder, like electrons excited in
their shells. Dripping with sweat
inside my custom-made spacesuit, I
shift my weight, so strangely
light, down onto my right foot, and touch
the moon. One small step,
launched from the shoulders of
all those who wanted to know, to
take that next step. My reptile
brain dimly recalls the feel of the first
claw that grasped the slimy ocean-edge, to
drag its living body, with its seed,
on through countless bodies, generations
of swimmers, runners, and
flyers, as far as
we can go.

A surprising number of poets are ready to step on the next spaceship, as Donald Hall cheerfully admitted to me that he would. Walter Lowenfels has a poem whose speaker sees "The Impossibilists" announcing, "Today is obsolete!"; they twist strands of DNA into new living creatures and predict Moon gardens (Vas Dias, 1970, pp. 168–169). X. J. Kennedy predicts what appear to be lunar mass drivers like those now being developed by Dr Gerard K. O'Neill's Space Studies Institute at Princeton: "Engines of slag careening from their track / into the unending dark, end over slow end," and he says, "It may well be that when I rev my car / and let it overtake and pass my thinking, / It's space I crave (Vas Dias, 1970, pp. 142–143). Stanley Kunitz's speaker in "The Flight of Apollo" (Vas Dias, 1970, p. 153) says from the Moon that he is

restless for the leap towards island universes pulsing
beyond where the constellations set. Infinite
space overwhelms the human heart, but in the middle
of nowhere life inexorably calls to life. Forward
my mail to Mars. What news from the Great Spiral
Nebula in Andromeda and the Magellanic Clouds?

And Richard Hugo (Vas Dias, 1970, pp. 115–116) welcomes our fusion into the future universe and the new forms of humanity into which we will evolve:

Beyond Van Allen rings, the stars
don't glitter, arrogant as moons.
When did we start? Light-years ago.
Why did we come? No matter. We
are not returning to that world
of ditch and strain, the research terms:
Cryogenic fuels, free radicals,
plasma jets, coordinated fusion.
Only the last, in all this void, applies.
A universe is fusing in our eyes.

Why return to air and land, when
free from weight and the weight
of hope, we float toward that blue
that kisses man forever out of form.
Forget the earth, those images and lies.
They said there'd be no wind out here,
but something blows from star to star
to clean our eyes and touch our hair.

Contemplating this vision and others like it, poets should not forget to acclimatize themselves to absorbing the machine that is making it all possible: the space shuttle. Diane Ackerman (1983, p. 32), in her poem on this latest hybrid between technology and humanity, one which allows us to transform the space beyond the atmosphere into more of the biosphere for ourselves, says of the shuttle astronauts:

In zero gravity, their hearts will be light,
not three pounds of blood, dream and gristle.
When they were young men, the sky was a tree
whose cool branches they climbed,
sweaty in August, and now they are the sky
young boys imagine as invisible limbs.

To summarize the 25 (by 1985, actually 27) years of NASA history and to predict its future, I offer my poem "The House that Jack Built."

In May, 1961, President John F. Kennedy told Congress: "I believe that this nation should commit itself to achieving the goal, before this decade is out, of landing a man on the moon and returning him safely to the earth." On July 20, 1969, flowers appeared on Jack Kennedy's grave, with the note, "Mr. President, the Eagle has landed."

This is the house that Jack built.

This is the rocket that flew to the moon
and back to the house that Jack built.

These are computers all over the world
that monitor spacemen who walk on the moon,
and splash down to the house that Jack built.

These are the men and women alert
at the Deep Space Network, spanning Earth,
who navigate spacecraft among Saturn's moons—
a new wing for the house that Jack built.

This is an astronaut floating safe and free
because thousands in Houston hold the other end
of the invisible lifeline to Mission Control,
where they keep the Orbiters flying like moons
high through the house that Jack built.

This is New Jersey, a garden at last,
and West Virginia, healed of strip mines past,
with industry in orbit. Solar sails riding sunbeams
float perfect crystals from asteroids to Earth, Earth
rising, swirling crescent in the moon's black sky.
This is why: the house that Jack built.

This is the spaceship Enterprise, the first to fly,
then Columbia, Challenger, Discovery, and then
Atlantis, for all the lost worlds we will find.
We command the fleet that sails by fire
to spin domed cities off of this Earth,
and make new earths out of planets and moons.
This is the house that Jack built.

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