

NASW-3724

FINAL REPORT

Space Ventures and Society; Long-Term Perspectives

William M. Brown

(NASA-CR-176012) SPACE VENTURES AND SOCIETY
LONG-TERM PERSPECTIVES Final Report (Hudson
Inst., Inc.) 189 p HC AC9/MF AJ1 CSCI D5A

NE5-30963

Unclass

G3/81 15520

HI-3731/2-RR

May 31, 1985

PREPARED FOR
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
UNDER CONTRACT NASW-3724



6201 Union Drive
Post Office Box 648 · Indianapolis, Indiana 46206
317-632-1787 · Telex 855-477

HUDSON INSTITUTE

FINAL REPORT

SPACE VENTURES AND SOCIETY;
LONG-TERM PERSPECTIVES

by

William M. Brown

HI-3731/2-RR

May 31, 1985

Prepared for

National Aeronautics and Space Administration

Under Contract NASW-3724

The views and conclusions contained in this document are those of the author and should not be interpreted as representing the official opinion or policy of the National Aeronautics and Space Administration or of other agencies of the United States Government.

HUDSON INSTITUTE, INC.
620 Union Drive
P.O. Box 648
Indianapolis, Indiana 46206

ACKNOWLEDGMENTS

This report revises and updates an earlier Hudson Institute study of space futures that was published in 1977.* Shortly after this second effort began Herman Kahn, Hudson's renowned research director and my long term colleague, passed away. Clearly this version would have benefitted a great deal from his contributions had he lived. Kahn, in my judgment, was not only an extraordinarily creative person but one of the great thinkers of our age.

In the present study I have retained the best parts of the earlier version, modifying them with the required editing and updating dictated by the passage of time. Other portions have been excised, new sections added, and the rest modified to create a unified portrayal of possible futures with a greater emphasis, however, on the critical role of societal developments. In the title the phrase, Space and Society, reflects that emphasis. Indeed the long term scenarios were selected to illustrate the enormous differences in outcomes which can result from changes in societal values.

Readers familiar with various publications by Herman Kahn may recognize his influence on this study. Some of that came about as a deliberate choice by me, and some from his influence upon my thinking that accumulated during about 25 years of close association. In those ways he has contributed toward the improvement of this study. I hope that my contributions are worthy of being associated with his.

One of the wholly new parts of this report is given in an Appendix by Barry Bruce-Briggs who provides an historical perspective on mankind's exploration of frontiers in order to see if there are parallels or lessons which would furnish guidance about what societal factors may motivate future space developments. Bruce-Briggs has helped make it clear that future public attitudes would probably need to be considerably different from past ones for space development to achieve a relatively optimistic outcome. In part that should become more likely as society moves, as it eventually must if it survives, toward a world in which essentially all people are wealthy relative to present U.S. standards.

I also wish to acknowledge that important contributions arose from the guidance and criticisms of Jesco von Putkamer, NASA's space enthusiast who monitored this contract. Jesco not only contributes to advanced planning in NASA's headquarters but is a visionary in his own right who has made many contributions to the outlook for space.

Finally I wish to thank Karl O'Lessker and Carol Kahn for reading and commenting on the final draft, and Susan Kane for bearing up under the load of repeatedly retyping without complaint the many drafts which preceded this one.

William M. Brown

*William M. Brown and Herman Kahn, Long Term Prospects for Developments in Space, etc.

TABLE OF CONTENTS

Chapter

I. PERSPECTIVE	
A. Introduction	1
B. Watersheds of History	4
C. The Difference that Space May Make	8
D. The Basic Surprise-Free Earth-Centered Scenario	9
II. POTENTIAL 21ST CENTURY SPACE DEVELOPMENTS	
A. Some Early 21st Century Technologies	13
B. Space Industrialization (SI)	19
C. Other Commercial Opportunities	24
D. Future Space Program: Near Term	27
E. Future Space Program: Long Term	33
III. AN OPTIMISTIC SCENARIO	
PART I: THE TRIUMPH OF THE MACHINE (1976-2000)	
A. The Explosion of Technology	45
B. The Early Space Program in the U.S.	46
C. The Earth-Centered Context	48
D. Improved Space Vehicles	51
E. Space Industrialization	54
F. Lunar Program	56
G. Early Space Tourists	57
H. International Cooperation	58
I. The Emerging Space Culture	59
J. Health Aspects of Manned Space Developments	60
K. Spinoffs	61
L. Milestones	63
PART II: FIRST QUARTER--21ST CENTURY	
A. World Economic Growth: A 100-Year Perspective	65
B. The Computer--Once More	66
C. Space Developments	67
D. Life Science in the Space Environment	71
E. Travel and Tourism	72
F. Demilitarization	73
PART III: REFLECTIONS ON DEVELOPMENTS FROM 2025 TO 2076	
A. Maturity in Space	75
B. Social and Economic Progress	75

TABLE OF CONTENTS (Cont'd)

Chapter

III. AN OPTIMISTIC SCENARIO (Cont'd)

PART III: REFLECTIONS ON DEVELOPMENTS FROM 2025 TO 2076

C. Automation	76
D. Computers and Electronics	77
E. Extraterrestrial	77
F. Space Vehicle Developments	78
G. Travel and Tourism	79
H. Interstellar Exploration	80
I. Solar Civilization Government	81

PART IV. FORECAST: THE NEXT 100 YEARS

A. Future Exploration	83
B. 100-Year Projections	85
C. A Universal Brain?	88

IV. TWO PESSIMISTIC SCENARIOS

PART I: THE CHINESE SOLUTION

A. 1976-2000	91
B. 2000-2025	115
C. 2025-2076	119

PART II: THE TRIUMPH OF THE GARDEN (2025-2075)
(A PESSIMISTIC SPACE DEVELOPMENT SCENARIO). . 125

V. A MODERATE SPACE DEVELOPMENT SCENARIO

PART I: A REVIEW OF SPACE HISTORY FROM 1985

PART II: THE NEXT 100 YEARS (2076-2176)

A. 1985-2010	117
B. 2010-2035	121
C. 2035-2076	124

VI. CONCLUSIONS	135
---------------------------	-----

LIST OF ACRONYMS	141
----------------------------	-----

BIBLIOGRAPHY	143
------------------------	-----

TABLE OF CONTENTS (Cont'd)

APPENDIX

A.	THE NEW CLASS	A-1
B.	HISTORICAL PERSPECTIVES FOR SPACE DEVELOPMENT by B. Bruce-Briggs with contributions by William M. Brown	
I.	2084: SPACE AND SOCIETY IN THE TWENTY-FIRST CENTURY	B-i
A.	Society	B-2
B.	Space	B-14
C.	Space and Society	B-14
II.	FRONTIERS IN TIME AND SPACE	B-17
A.	The Sea Frontier	B-18
III.	COLONIZATION-TERRESTRIAL AND EXTRATERRESTRIAL	B-36
A.	Trans-Medium Settlements	B-36
B.	In-Medium Settlements	B-44

LIST OF FIGURES

1. Annual Worldwide Investments in Space Ventures For Various Assumed Growths	20
2. Transportation Costs to Near-Earth Orbit	26
3. Advanced Resources/Pollution Observatory (CO-1)	29
4. Coastal Anti-Collision Passive Radar (CO-9)	30
5. Atmospheric Temperature Profile Souncer (CO-11)	31
6. Personal Communications Wrist Radio (CC-9)	32
7. Space Tourists/Year	37
8. La Grange Points of the Earth	41
9. Commercial Sales of Satellite Data	52

LIST OF TABLES

1. Surprise-Free Projection of World Population and GWP for the Basic 10/20/200 Scenario	10
2. Some Early 21st Century Technologies	14
3. Some Forecasts for Ultra Sensitive Sensors	18
4. Progress in Space Technology, Past and Projected	21
5. Ten Advantages of Operating in Space	23
6. A Suggestive, But Hardly Exhaustive, List of Space Manufacturing Activities	25
7. Near Term Potential Space Applications	28
8. Keys to Long-Term Optimism for Developments in Space	35
9. Projected Annual Investments and Production in Space	39
10. Federal Budget And NASA Appropriation, 1961-1984	47
11. Orbital Transfer Vehicles in Operation or in Development before 2000	55
12. U.S. Space Development Milestones	64
13. Optimistic Scenario: Population and Gross Product (Past and Projected)	87
14. Chinese Space Travel Data	106
15. Highlights of U.S. Space Accomplishments, 1985-2010	119

Chapter 1

PERSPECTIVE

A. Introduction

This report tries to present some useful and interesting images related to the potential long-term future in space. One of its purposes is to encourage and facilitate the use of such images by NASA in its studies, planning, and public information programs. Although NASA already uses various scenarios in its planning, the deliberate formulation of long-term scenarios or "realistic images of the long-term future" is usually left to others. It may now be timely, perhaps important, for NASA to participate in this process--to encourage and facilitate it. The public's interest in space programs undoubtedly will be related to their perceptions about how glorious and exciting space development can be.

Clearly, television shows, movies, the news media, science fiction and other popular literature have already introduced much of the public here and abroad to a variety of space concepts. However, existing literature on space technology as interpreted by these media is seldom well disciplined, although it is often imaginative. Also, with some important exceptions, it is relatively unrelated to serious socio-political issues. A goal of this report is to help fill this last gap, particularly in relating social issues to potential space programs. In several fields the historical record suggests that carefully-developed images of the future have often helped to place current priorities, issues, or controversies into a more realistic context, and have provided perspectives useful for understanding them. For Americans long-term space-development scenarios which give rise to shared images of space futures can contribute to their sense of community, to institutional meaning and purpose, to morale, and even--to use somewhat extravagant terms--to perceptions of their manifest destiny or "religious" mission. It will be important to focus on goals which are feasible and practical. Thus appearances of fanaticism, unwarranted risks or unduly utopian outcomes in the near-term should be avoided by responsible institutions. Such images, if expressed by NASA officials at inappropriate times and occasions, could create counter-productive responses.

This report presents its scenarios from the vantage point of a U.S. space historian who is living in the year 2076 and looking back over "history." This is partly a dramatic device but it also is convenient as it provides a stimulating perspective. For example, the "historian" also attempts to project developments for the "next 100 years in space" and observes that it is not possible to offer much more than interesting conjectures.

In this report are ingredients which could interest almost anyone interested in writing or outlining long-term space scenarios. Not only are there suggestions for other scenarios, but also contexts, orientation

and information which might be helpful. The chosen scenarios are developed at some length to illustrate in detail how they can be created. The Moderate scenario is intended to be the most likely and persuasive; however the others, represent less-limiting cases of pessimism and optimism (from the perspective of a space professional) might be more appealing because they are more dramatic. Still all of them appear to be possible, and none implausible.

The huge number of possible future changes permit an almost endless variety of scenarios to be constructed. The key ingredients for success in space over the long-term are listed and discussed in Chapter II where it is shown that these prospects depend upon several factors ranging from highly technological developments to the soft matters of future social dynamics. Indeed, the major variable which influences the outcome of the scenarios in Chapters III, IV, V are the assumptions about the new values which successful industrialized societies adopt over the long-term. In the most pessimistic scenario (pessimistic as seen by space buffs) the emerging new values emphasize safety, security, welfare, health, and environmental purity. Science, technology and new industrial developments are viewed as dangerous--as creators of potential threats to society that must therefore be increasingly and carefully regulated. That emerging ideology induces social forces which restrain technological progress, as it is currently understood and measured, in favor of a simpler, slower, but more secure existence. Indeed, that kind of outcome reflects many of the values which emerged in the U.S. between the mid 1960s and the late 1970s and which have been strongly associated with the rise of the public-interest movement whose activists were inclined toward political liberalism as defined during those years. These activists and their supporters have been called "the New Class," a term which is also used in the scenarios. A description of the New Class phenomenon is given in Appendix A.

In the context of the Optimistic Scenario it is important to observe that a successful affluent world does not necessarily lead to an emphasis of New Class values, at least not to the extent that it would stifle most new technological developments. Consequently the New Class phenomenon does not become an important constraining factor. But much more is needed to make the Optimistic Scenario a vibrant possibility.

First, it is necessary for the people of nearly every nation to acquire a basic confidence in their future security, economic and political. Up to now that kind of security has been rare in the world and incomplete within any nation. Because of widespread insecurity during every era of human experience, history itself does not provide much hope or guidance for future long-term optimism in space development. A search for historical lessons is given in Appendix B. However, the results of that search, alone, would suggest that the only solid hope for optimism in space would rest upon its potential for returning sufficient amounts of wealth, knowledge or power to those who invest in space.

Although it is indeed possible that the resources to be found in space coupled with improving technology would, over time, provide many investment opportunities with large payoffs in "crass commercialism" or in military advantages, such outcomes cannot be expected to lead to the complex socio-political changes which are required for the Optimistic Scenario. Something more is needed, a vital "ingredient" which reflects the long-term needs and desires of the human spirit and which will encourage a blossoming of mankind's potential. But at the same time it must be so practical that, once understood, its emergence cannot be denied.

It is probably correct to surmise that preconditions for the widespread emergence of that new spirit include (1) a spreading confidence among nations that the threat of large scale international warfare will diminish over time and before long become utterly obsolete, (2) an institutionalization of minimum standards of economic security, rising over time, and available to the citizens of essentially every nation, and (3) a growing belief that improving worldwide education and training coupled with expanding opportunities for utilizing it, will lead to an endless series of social, economic and technological "miracles" which will be the milestones along the future path of mankind's inevitable ascent, literally and figuratively, to the heavens.

Indeed the above paragraph defines a set of preconditions which should not be too difficult to achieve. Many of the "forces" are already in place--for example, growing wealth, improving technology, diminishing utility of war, expanding communications, and a burgeoning interest in assisting disadvantaged cultures of countries. But is this enough? If not what other ingredient might be crucial? Might it not be a new quasi-spiritual idea which in a modern form reflects the ultimate potential of the human spirit? Might it not take the form of a belief in mankind's destiny that sees the human race as emerging triumphantly over all natural obstacles and establishing its presence on a large scale throughout the solar system, from which it could then choose to move out, when ready, toward the rest of the awesome universe?

A general surge toward that kind of perceived destiny would certainly require a similar appropriate spirit to arise and spread throughout the world. It would almost certainly have to become the focus of a changing orientation of people toward each other and their institutions. This spreading image of mankind's destiny would require a new humanism, and a growing humanitarianism, on earth which would help to mobilize the world's potential for accomplishing the great missions ahead. To best reach out toward that goal all of the earth's billions of people should be potential contributors. Opportunities must then be created to help the presently disadvantaged to modernize and participate with the advantaged. As in other humanitarian efforts, the effective assistance given will provide a more promising world for everyone.

Might not the world's present effort in space provide the above kind of inspiration to the rest of humanity? Certainly not! But it could have a key symbolic role to play. As a reflection of mankind's tangible progress in science and technology it may be ideal. As a symbolic spearhead of mankind's announced intention to conquer the technical, economic, political and social impediments to mankind's ascendance it may be nearly perfect. As an ongoing measure of human progress toward an evolving perception of its destiny it is excellent.

It is clearly evident that successes in space exploration are profoundly influencing a growing, and largely youthful, segment of world society that is now becoming organized into active groups to support further space exploration. It is mainly from the youth (the young in heart) that an appropriate spirit can be expected to grow. If that spirit becomes nurtured in an expanding humanistic context, as indicated above, it should greatly increase the likelihood that some form of the Optimistic Scenario, depicted in Chapter III, will become a part of the world's future.

B. Watersheds of History

Perhaps the two great technological watersheds of human history prior to the 20th century were the agricultural revolution, which started in the Middle East some 10,000 years ago, and the industrial revolution, which began in Holland and England about 200 years ago. Of course, many historians and futurists now are claiming that the second half of the twentieth century is witnessing the beginning of another watershed. Some would emphasize the computer-based electronics, some the introduction of nuclear energy and explosives; some would emphasize the ability of man to leave and return to the earth; some would emphasize the peaking of growth rates in world population and gross world product; some would emphasize the universalization of the industrial revolution; while finally some would emphasize almost the opposite--the emergence of physical or social "limits to growth."

In any case, in much the same way that the agricultural revolution was destined spread around the world, the industrial revolution is still spreading and causing a permanent change in the quality of human life. However, instead of taking 10,000 years, this second diffusion process is likely to be largely completed within a total span of about 400 years, or roughly by the mid or late 22nd century. Indeed, what has been termed the super-industrial and post-industrial economies are even now emerging, to be followed eventually by corresponding changes

in society and culture as a whole.* The last part of this period may be accompanied and followed by an era of space exploration and exploitation which may introduce an equally startling change in human history. In fact, one of the purposes of this report is to use the scenario technique to explore, dramatize, and illustrate some of the possible interactions of a developing "outward-bound" culture with cultures and events on earth--and, in particular, to illustrate how such developments in space might affect the "post-industrial culture" on earth, and be affected by it.

In order to characterize the nature of some changes that will occur, it is useful to distinguish four kinds of activities: primary, secondary, tertiary, and quaternary.

Primary activities are extractive, principally agriculture, mining, forestry, and fishing. They would be similar to the major occupational activities pre-industrial society, one mostly organized to "play games

* Various authors have developed and expanded notions of "post-industrial" economy, society, and culture. Preeminent among these in the depth and sophistication of their analysis are Daniel Bell, The Coming of Post-Industrial Society; A Venture in Social Forecasting (New York: Basic Books, 1973), and, with a very different manner and emphasis, Peter Drucker, The Age of Discontinuity (New York: Harper & Row, 1969).

We should distinguish here among:

Economy:	economic and technological activity
Institutions:	laws and organizations
Culture:	style, values, national character and attitudes
Society:	the whole

Super-Industrial Economy refers to large size and scale of modern enterprise and the importance of its impact on the external social and physical environment.

Post-Industrial Economy refers to a future very affluent economy which meets its industrial and material needs with a small percent of its work force and economic effort. The term is deliberately chosen to be neutral; it does not describe the corresponding society.

Presumably the economy emerges first; then the institutions and the culture change; finally (hopefully), a harmonious society evolves.

Post-Industrial is often at the same time Super-Industrial. Thus, the United States is a post-agricultural society (since less than five percent of its inhabitants are engaged seriously in agriculture) but it is also a super-agricultural society in terms of the variety of its products and the scale of its activities.

with and against nature."* In those days for each city dweller there were generally about twenty living in rural areas and following some primary activity.

Secondary activities mainly involve construction and manufacturing. That portion of society and its culture is mostly organized to "play with and against materials." It is primarily an urban culture which has been characterized in recent history by a nation-state political system with its well-known characteristics.

Initially, an emerging post-industrial economy will be characterized by a service economy, emphasizing what we call tertiary activities. These are services which assist primary and secondary activities as well as the functions of the nation-state. Conventionally they include transportation, insurance, finance, management, governmental activities, education and training. This trend is toward society and culture whose major activity is "games with and against organizations." Such a society is increasingly characterized by organizational and professional pluralism in the distribution of power, wealth and prestige. It will probably become more suburban than urban, and will tend to move toward a larger fraction of corporate activities.

By early in the 21st century, a partial transition (in the richer OECD countries at least) to a different kind of service economy should have occurred that can be called a "quaternary" or truly post-industrial economy. In such a society the primary, secondary, and tertiary activities will constitute only a small part of human endeavor; more and more will people do things for their own sake, and ends will become more important than means. Such a society can be characterized as playing games with and against people, with and against communities; and perhaps, even with and against oneself. These quaternary activities could include many "mundane" activities such as:

Reading, writing, painting, acting, composing, musicianship, arts and crafts--particularly if done for their own sake.

Tourism, games, contests, rituals, exhibitions, and performances.

*The term "playing games with or against nature" and other uses of game metaphors refer to the extensive literature of gaming, simulation and role playing and should be thought of partly in a literal sense and partly metaphorically. The idea simply is that the major roles and activities of the individual in a primary society are preoccupied with activities which can be characterized as "playing games with and against nature" rather than as in the other cases "with and against materials," "with and against organizations" or "with and against communities." The basic inspiration for this terminology comes from Daniel Bell.

Gourmet cooking and eating, an aristocratic and formal style of life, epicurean and family values (including visiting, entertaining and "togetherness").

Hunting, fishing, hiking, camping, boating.

Acquisition of non-vocational skills.

Improving property (if caused by some non-economic motives), such as gardening, upkeep, interior decorating, and the use of home-made artifacts.

Conversation, discussion, debating, and politicking.
Many other cultural and social activities.
Most welfare and social security.

Other "recreation," including the search for change, broadening experiences, adventure, excitement, and amusement.

But also such significant activities as:

Many public works and public projects done more for cultural interest than for economic or research reasons (e.g., space activities, under-seas exploration, much environmental protection, monumental architecture).

Ritualistic and aesthetic activities (perhaps creating special structures and environments) including the evoking of images or feelings of splendor, pride, pomp, awe, and communal, ethnic, religious, or national unity or identity; oneness with nature and the universe, and various explorations in "inner space."

The creation of taboos, totems, demanding religions, traditions, and customs; arbitrary pressures, constraints and demands; moral and social equivalents of war; some other pressures and risks, including those involved with some of the more bizarre forms of "discretionary behavior."

Finally, the concept includes non-tertiary services to these and other quaternary activities.

If a transition occurs to a society principally engaged in these activities--a transition which could largely be completed some two hundred years hence--it would probably mark the third great watershed of human history. Future society would look back at what happened in these centuries of industrialization and describe it as mankind's most effective and pervasive transformation--a journey from a world basically inhospitable to its relatively few dwellers to one fully commanded and enjoyed by its expanded multitudes.

C. The Difference that Space May Make

Nevertheless, many readers may be at least a little uneasy with the above images. It ends too soon. Would mankind choose to "stagnate" in a totally quaternary society? Would it permanently give up its games with and against nature, materials and organizations? One guess is that in the future mankind will reply, "not completely." Still, it is clearly possible for most people to become content within this post-industrial culture. In other words, most people could be quite happy living in this postulated quaternary culture, but there are likely to be many who would become restless within it. These people might find the culture lacking in excitement, challenges, and opportunities. Ambitious people would undoubtedly want to contribute to larger goals, rather than merely accepting and reinforcing the even tenor of a rich, comfortable and even, within its own terms, interesting life. Indeed, the development of space could become a major focus for many of these people. The existence of such a frontier with an endless scope for activity and of such a locus of dynamism, initiative, and entrepreneurship should be very healthy for the quaternary society that prefers to remain earth-bound as well as for those who may attempt to faster progress--either as a society, a family, or individual, or as an industrial or professional group. In such a manner the endless challenge of space could, first psychologically and culturally, and then materially, play a central role in making the future a much more interesting experience (this potential is developed most strongly in the Optimistic Scenario, Chapter III).

At least three possible space perspectives seem to be interesting: (1) Not important: that is, space doesn't make crucial or dramatic differences within the next 200 years; (2) Crucial: Space has an essential role in changing the world from a stagnant neo-Malthusian orientation to a hopeful outward-bound post-industrial one. (3) Useful: Space activity complements and enlarges post-industrial development but is not essential to it. However, it improves the context for developing a superior post-industrial society on earth and may create a much different society living in space.

Thus, post-industrial society need not end mankind's future but can provide a base from which to move deep into the solar system and then, possibly, into interstellar space. Whether or not the latter occurs, the openness, the opportunities, and the challenge of outer space can cast a sustained and profound influence upon an otherwise excessively static or introspective earth society.

This study will emphasize the possibilities that income and resources from space can be important, that space activities can generate many economically and technologically profitable enterprises, and that the exploitation of space can have a major and positive influence on the world's economic, technological and ideological future. Such outcomes are

consistent with both the second and third perspectives above. However as the first two perspectives are in conflict one of them may have basic flaws.

D. The Basic Surprise-Free Earth-Centered Scenario

It is useful to begin any projection of the future with a reasonable-- or not unreasonable--surprise-free scenario which unfolds over time at least some of the simplest "data" that can measure or set limits to economic, demographic, and technological trends. It may not be possible, of course, to get futurologists to agree that any particular set of data should be preferred, because a strong divergence of views usually exists--a divergence which, in part, reflects a genuine uncertainty. But it is usually possible to get a fair amount of agreement that a particular choice is not stupid, ridiculous, wildly optimistic or pessimistic, etc.

However, even achieving agreement might be irrelevant. For example, the average economic growth rate per capita for today's most developed countries has, over the last 200 years, been roughly 2.0 percent. Over the 200 years this increase in income is about a factor of 50, from about \$150 to about \$7,500 per capita. However if a serious 200-year economic projection had been made in 1776 for the newly-born United States, using the 2 percent figure, almost all intelligent and knowledgeable people probably would have sneered at or ridiculed it. After all, at that date the world had scarcely changed in average per-capita income since the beginning of recorded history. Indeed, had such projections then been based upon a 1 percent or a 3 percent growth rate (neither of which, in retrospect, appears any less plausible than 2 percent) the actual outcome over the two centuries would have changed radically--by about a factor of 7--that is, to \$1,000 per capita or \$50,000 per capita, respectively.

Even with the recognition of the powerful effect of small changes in average growth rates upon the long-term outcome, and therefore of the low probability of making valid estimates over extended periods, it is still necessary to begin somewhere. The choice here is a surprise-free projection adapted (and slightly modified) from the Hudson Institute book, The Next 200 Years. The chosen population and economic projections are shown in Table 1. They were arrived at after due deliberation but are, of course, arbitrary to some degree. They were chosen almost as much for convenience and general acceptability as for a serious prediction, and are based on a smooth curve (i.e., no attempt is made to include short term effects of business cycles). This choice may be called a 10/20/200 world as it asymptotically approaches the values: 10 billion

*The modifications are partly due to recent data and events. The principal change is the 200-year projection to a 10-billion world population, rather than 15-billion. The GNP/capita over time is about the same.

Table 1

SURPRISE-FREE PROJECTION OF WORLD POPULATION AND GWP*
FOR THE BASIC 10/20/200 SCENARIO

<u>YEAR</u>	<u>POPULATION (BILLIONS)</u>	<u>GWP (AVERAGE) (\$ TRILLION)</u>	<u>GWP/CAPITA (AVERAGE) (\$ THOUSANDS)</u>
1975	4.0 (2.0)	6.6 (5.1)**	1.75 (2.8)
2000	6.0 (1.3)	20 (3.6)	3.3 (2.3)
2025	7.7 (.7)	43 (2.6)	5.6 (1.9)
2050	8.8 (.4)	74 (1.8)	8.5 (1.4)
2075	9.4 (.2)	106 (1.2)	11.0 (.97)
2100	9.7 (.1)	135 (.75)	14.0 (.66)
2125	9.9 (.04)	156 (.47)	16.0 (.43)
2150	9.9 (.02)	172 (.29)	17.0 (.27)
2175	10.0 (.01)	182 (.18)	18.0 (.17)

* GROSS WORLD PRODUCT AND GWP/CAPITA IN 1975 DOLLARS. THE FIGURES IN PARENTHESES GIVE PERCENT CHANGE PER ANNUM DURING THE FOLLOWING 25 YEARS.

** THE 1975 GWP IS USUALLY ESTIMATED AT \$6.3 BILLION AND THE GROWTH RATE WAS MUCH SMALLER THAN 5.1 FOR THAT YEAR. WHAT APPEARS ABOVE IS THE CALCULATED RESULT OF A SMOOTHED OUT PROJECTION WHICH CORRECTS FOR THE 1974-5 RECESSION.

population, \$20,000 GWP per capita and \$200 trillion GWP (1975 dollars are assumed throughout this report unless otherwise specified).

The population projections are reasonably consistent with those made by the United Nations. They assume that the world population stabilizes after about a century (if it doesn't, some serious social problems could arise). More controversial, however, is the assumed growth in GWP which, after 200 years, increases the world's average per capita income about a factor of 10. That is, this surprise-free world becomes rich, even by current U.S. standards. Still the factor of 10 represents an average projected growth rate over 200 years of only 1.2 percent in per capita income--a rate which would be a great disappointment currently in any growth-oriented nation. Indeed, the estimates in Table 1 show a conservative (in the light of present trends and the ongoing technological revolution) per capita growth rate of only 2.3 percent for 50 years to 2025. For the last 100 years, 2075-2175, it is substantially less than 1 percent. In this light the end result can hardly be termed optimistic--yet it has often been so labeled (by critics of The Next 200 Years).

Probably the principal reason for the "optimistic" label is the legacy of the pessimistic belief, which became widespread in the mid-70s before it faded, that the world simply has insufficient resources to sustain nations with growing populations and growing economies much beyond their present sizes. It should not be surprising if present adherents of that view are taken aback by a claim that the population could more than double and the gross world income increase almost 30-fold without unduly straining the physical capacity of our "small" world. Yet, according to the analysis of the The Next 200 Years, this economic projection appears to be only a very moderate one, well within the capacity of the world's resources.

The scenarios in the later chapters of this report start from this surprise-free context. Only the most pessimistic one is unable to rise above it. The Optimistic Scenario does much more. It accomplishes the 200-year outcome within 100 years, and proceeds on a rapid growth path to some remarkable accomplishments.

* Although few people are likely to object to a population limit many might object that a limit to GWP is not reasonable, even in an earth-centered context. The assumption of a GWP limit merely reflects a mathematical convenience in which at the end of the year 200-year period the world economies are still growing, but slowly, at about .25 percent annually.

Chapter II

POTENTIAL 21ST CENTURY SPACE DEVELOPMENTS

A. Some Early 21st Century Technologies

In the future it is possible, as a result of past successes, for most of the developed world to become relatively hostile to innovation in science and technology. By blaming it, for example, for the dangers that it has unleashed (nuclear weapons, pollutants, hazardous chemicals, etc.) it can be claimed that technology is likely to create more harm than good and should either be stopped or severely constrained. Whatever the outcome may be as such restrictions are attempted, it appears that enough momentum exists in current technological efforts that a surprise-free projection into the early 21st century would very likely include the developments shown in Table 2. Some remarks about this table are in order.

1. Recent international interest and continuing expenditures to develop many alternative energy sources will provide assurance of the availability of relatively inexpensive and clearly inexhaustible supplies well before the middle of the 21st century. The first oil crisis associated with the Arab embargo of 1973 and its price surge, followed by the second oil crisis in 1979-80 will be long remembered as a particular vulnerability that gradually must be eliminated to assure a secure long term future. Energy may not become as cheap as it was in 1970 but it certainly does not need to be expensive. Indeed, the world's technological community can be expected to strive diligently until this assertion becomes valid. Because no fundamental reason requires clean energy from relatively long term or inexhaustible sources to be expensive, and because a large number of alternatives are now being pursued around the world, to knowledgeable observers only a very pessimistic conservative or a neo-Malthusian advocate would be apt to dispute this conclusion. Moreover, by coupling new energy supply alternatives with the potential of efficient utilization practices it may even be possible that the effective cost of energy may become quite inexpensive--possibly even cheap--once again. The effective cost, of course means the total economic cost to perform the required task--heat a building, drive 100 miles, make a ton of steel, illuminate an office, provide a megawatt-hour of electricity, etc.

2. "Pollution-free" industries and improved recycling are obviously symbiotic. A major trend in industrial research today is to convert pollutants into resources. Sulfur is being recovered more and more in the form of useful by-products rather than emitted in noxious fumes. Low levels of metallic compounds in liquid wastes are now being recovered, thereby reducing pollution and recycling the valuable minerals. Urban wastes are being transformed into fuel and mineral resources. These few examples illustrate the technological trends which are likely over time to eliminate current doubts about the ability of science and technology to

Table 2SOME EARLY 21ST CENTURY TECHNOLOGIES

1. INEXPENSIVE AND INEXHAUSTIBLE ENERGY SOURCES
2. "POLLUTION-FREE" INDUSTRIES PLUS IMPROVED RECYCLING
3. LARGE ADVANCES IN DRILLING AND MINERAL EXTRACTION
4. LARGE-SCALE UNCONVENTIONAL AGRICULTURE AND ARTIFICIAL FOODS
5. SUBSTANTIAL MATERIALS PROGRESS IN FIBERS, FOAMS, COMPOSITES, CERAMICS, CRYSTALS, POLYMERS, ADHESIVES
6. ULTRASENSITIVE SENSORS (SEE TABLE 3)
7. HUMAN-MACHINE COMMUNICATIONS

LARGE IMPROVEMENT FACTORS IN HARDWARE BY YEAR 2000

. OPERATING SPEED	10^{-10} to 10^3
. STORAGE CAPACITY	10^5 to 10^{10}
. RELIABILITY	10^3 to ?
. INFORMATION TRANSFER RATE	10^3 to 10^5

SOFTWARE IMPROVEMENTS

. DATA COMPRESSION	2 to 1000
. PROGRAMMER PRODUCTIVITY	10 to 100
. VOICE COMMUNICATION	?
. AUTOMATIC PROGRAMMING	?

8. AUTOMATION: IMPROVED MACHINES
TELEOPERATORS
ADVANCED ROBOTS
INTELLIGENT ROBOTS
9. IMPRESSIVE ADVANCES IN GENETICS AND MEDICINE

reduce and recycle pollutants effectively. By any reasonable historical measure the recent response to society's demands for an improved environment has been rapid and effective. Clearly as long as society demands it (and is willing to pay the costs involved) this trend will continue.

3. Within the last ten years at least twelve novel or revolutionary design concepts for new drill bits have been announced. Yet the bit is not the only part of the drilling process that is being improved. Other improvements in exploration and extraction industries are being made through the use of processed LANDSAT data, new downhole sensors, the application of computers to analysing the raw data from seismic sensors and mapping the geological structures, and the development of new technologies for recovering various minerals from the oceans.

Currently there is little doubt that progress in the extractive industries will soon make petroleum exploration possible at almost any ocean depth on the continental rises, as well as the gathering of mineral bearing nodules on the deep sea floor. The concerns of the 1970s about adequate long term supplies of both energy and minerals from secure sources has been coupled with powerful advancing technologies to effectively guarantee extraordinary progress in extractive industries over the next few decades and probably for much longer.

4. In discussing future world food requirements it should be noticed that many avenues to unconventional agriculture and artificial foods have already been opened and are now commercial, although some are not yet producing on a large scale. But the trend seems clear. Single-cell protein is being widely used as a supplementary animal food and is now manufactured on a large scale. The industry has predicted that within a decade the purity of the product will meet existing standards for human consumption and at not more than half the cost of competing protein rich foods (e.g., soybeans). Scientifically controlled growth chambers now exist on a commercial scale with yields in vegetable crops from 10 to 100 times greater than that from conventional agricultural land. These chambers are capital intensive year-round 24-hour operations. Their principal competitive determinant appears to be related to a single technical problem: how efficiently can energy be converted into the light frequencies which produce photosynthesis. This is the kind of problem in which a major breakthrough can occur in any year. It would be surprising if one hasn't happened before the year 2000. Also, the nutrient film technique developed in England by the Glasshouse Crops Research Institute is used to grow vegetables commercially in thin polyethylene troughs, without soil. This technique has been spreading rapidly and its application to cereals is currently under investigation.

Scientists have found a way to increase soybean yields from 30 to 60 percent by a carefully controlled application of foliar spraying. Companies are now commercially producing tortula yeast, a food made from petroleum that has twice the protein value of beef. A chemical found in alfalfa has increased the yield of several greenhouse crops from 10 to 40 percent and may be applicable to conventional farming.

There are but a few examples of a very long list of promising new approaches to food production. These innovative and unconventional approaches to food production could become a major factor in food supplies within the next two decades.

5. Partly in response to the requirements of the aerospace and other high technology industries and partly because of recent rapid advances in diagnostic instruments and computer aided analysis and design, unusually rapid advances have been announced in a wide variety of materials--some of which are indicated in Table 2. Fibers of graphite, plastics and glass are now stronger than high tensile steel. An "endless" parade of new foams are being used to provide greater rigidity and/or insulation (against heat, electricity, or shock) with a minimum of material. New ceramics are offering both extreme hardness and tolerance of extremely high temperatures. Crystals of very high purity and uniformity in structure provide unusual properties which have already made possible such devices as microcomputers, lasers, and most recently light "pipes" for communications. Production of polymers has become a huge growth industry--especially in plastics--and is expected to continue growing for a long time. Lastly, a remarkable array of adhesives have effectively been challenging the techniques of bonding with welds, rivets and other fasteners.

The progress in materials has been so remarkable that in some instances the theoretical limit to such material properties as strength, hardness, and bonding may be attained by the end of the century. However, the potential for new composites, new geometric designs, and new materials with unusual properties appears to be almost endless. Scientific progress in understanding the properties of materials is occurring ever more rapidly with the aid of new analytical instruments combined with high speed computers. These improved materials have already contributed immensely to the development of space vehicles and satellites and are expected to make possible not only lower propulsion costs but greater performance within a given payload weight.

6. The astonishing improvements which have been made and which are expected to be made in sensors (see Table 3) will have a tremendous impact on science and technology. In some cases, as can be seen, sensors have approached or reached the theoretical limit (reduced noise levels, for example). In most cases, however, the potential for improvement is either open ended or very far from any such limits. Thus the kind of progress shown in Table 3 can continue well into the 21st century, or beyond. These kinds of improvements hold an immense potential for serving mankind in general and space development in particular.

7. Progress in computers, already awesome, will continue throughout this century, at the very least. Table 2 shows some current projections for hardware as well as for software which is more difficult to project. The degree to which computer technology will change society during the 21st century can only be immense. Very likely its potential impact on the world is far from being understood as there has not been sufficient time even to

experience the full impact of the current capability--a process which would undoubtedly take at least several decades if new developments were to be stopped. However, after a few decades computers should be from a thousand to a million times more effective than they are today--depending on the applications. It is probably not possible to foresee, even in general terms, the major ways in which the social structure of the world's societies will be changed by the application of computers over a century or more.

8. Some of the potential applications of computers to automation can be understood to a degree. Microprocessors are destined more-and-more to control our motor vehicles, appliances, communications, and laboratories, as well as our factories, offices and homes. For remote maintenance (such as in outer space) teleoperators will undoubtedly become common.

The Viking landers on Mars were probably the world's most advanced robots in the mid-70s. That only represented an early milestone in the beginning of robotics. That future robots can become much more "intelligent" than current ones is not doubted even when we restrict our conceptions to machines of limited learning capabilities. But can they eventually become intelligent in the human sense? That is an ongoing, unresolved debate among scientists specializing in the field of artificial intelligence.

9. Perhaps the most spectacular scientific and technological advances have and, in the near term, will continue to occur in microbiology. The implications of increasing knowledge in this field and its application to genetic control, and to the prevention and cure of diseases--physical, emotional, and mental (if these are proper categories)--is truly exciting. Certainly, there is a reasonable chance that essentially all bacterial and viral diseases can be prevented or rapidly cured before too long--many perhaps, even by this century's end. Progress in this field has been intimately associated with progress in the sciences of physics, chemistry, and biology, and in the technologies of computers, analytical instruments, sensors, and pharmacology. A remarkable integration among these disciplines has led to astonishing advances which appear to be only the beginning of much greater discoveries and applications to come.

10. For future progress in space development--especially for manned operations in space which are currently visualized as space laboratories, permanent space bases, space industries, colonies in orbit or on planetary bodies, and space explorers--all of the technological developments described above will be very important. They will be crucial in determining the long term growth in space. For example space industrialization at the end of the next century will be vastly different depending upon whether the annual growth rate is 2, 5 or 10 percent (Figure 1). The 2 percent figure is barely interesting in less than 100 years: the 10 percent growth rate, however, would soon spawn results similar to those of far-out science fiction. To mention exponential growth alone without specifying the quantitative rate leaves obscure the critical factor--the doubling rate. That will, of course, depend on social and political developments as well as new technologies. Some of these

Table 3

SOME FORECASTS FOR ULTRA SENSITIVE SENSORS

	<u>1970</u>	<u>1980</u>	<u>1990</u>	<u>2000</u>
MICROWAVE RADIOMETERS				
NOISE TEMP. (K)	2000	300	30	30
APERTURE (METERS)	1	2	10	40
RADIO TELESCOPE				
SENSITIVITY AT 1-GHZ	1	.02		.01-.001
RADAR RESOLUTION, FROM EARTH				
ORBIT (METERS)	5	3½	2	1
SPACE TELESCOPE:				
APERTURE (CM.)	50	200		350-450
LASER ABSORPTION SPECTROMETER,				
ABS, COEFF.	4	10	12-100	10 ² -10 ⁴
MULTI-SPECTRAL IMAGERS,				
RESOLUTION (MICRO-RAD.)	100	25	10	7
SOLID STATE CAMERA (CCD)				
RESOLUTION (NO. OF ELEMENTS,				
MILLIONS)	--	1.1	5-7	11-30
PHOTON SENSITIVITY				
(MICRO-JOULES/M ²)		.02	.01	.008
X-RAY TELESCOPE (20-300 K.E.V.)				
SENSITIVITY	1	.2	.03	.006
X-RAY SPECTROMETER (20-300 K.E.V.)				
SENSITIVITY	4	.2	.01	.001
SUPERCONDUCTING MAGNETIC				
SPECTROMETER, INDEX	1.5	7-8	25-50	90-250
MAGNETS (KG. PER KILOGAUSS)	1.5	.5	.1	.001
GRAVITY GRADIOMETER	1	.01	.001	.001

SOURCE: NATIONAL AERONAUTICS AND SPACE ADMINISTRATION, A FORECAST OF SPACE TECHNOLOGY, 1980-2000, SP-387 (WASHINGTON, D.C.: SCIENTIFIC AND TECHNICAL INFORMATION OFFICE, JANUARY 1976). THIS TABLE IS AN ADAPTATION AND PARTIAL SUMMARY OF SOME OF THE DATA AND FORECASTS PRESENTED.

developments will be incorporated in the subsequent scenarios and, by their impact on the doubling rate, lead to vastly different worlds.

The progress which has already occurred in space technology and that which might be expected to occur over the rest of this century under reasonably optimistic conditions (adequate funding and/or good luck) are illustrated in Table 4. The data for this table have been taken from NASA sources, principally from its 1975 Outlook for Space study. Those projections generally were based upon careful evaluations by eminent scientists and technologists and are as likely to be understated as overstated. Where a range is given in the projected progress the principal consideration is the available funding. For example, to achieve the major reductions in launch costs would probably require at least \$10 billion (in 1975 dollars) for the development of a large capacity reusable unmanned vehicle. The principal implication to be drawn from the table is that some astonishing space developments are likely to occur within the next 20 years--developments that might even surprise technological optimists who are not specialists in space technology.

B. Space Industrialization (SI)

A decade ago it was a somewhat bizarre idea. However it is now generally assumed that the industrialization of space, in the sense of manufacturing operations conducted in or beyond low-earth orbit, is certain to happen. Because of its embryonic nature its early growth rate is highly uncertain. Research and development on processes for future SI installations have been pursued in space as well as in earth laboratories for several years. The three Skylab launches were the first extensive manned R&D operations conducted in space that focused upon the SI concept. The results of these and subsequent efforts led science writer G. Harry Stine to claim that a "third industrial revolution" was about to start.

Why industrialize space? The answer must be essentially economic. Clearly there must be some important commercial operations which can be done only in space and others which can be done better in space. That is, the space environment has exploitable advantages or resources that are unavailable or relatively costly on earth. Some of the principal ones now known are listed in Table 5.

Such advantages could become impressive. They could make feasible a large array of new products and processes with great commercial value. Designs already exist, for example, for Solar Satellite Power Systems

* G. Harry Stine. The Third Industrial Revolution (New York: G.P. Putnam & Sons, 1975). Also, for an early NASA study on the SI potential see Rockwell International, Space Division, Space Industrialization, Final, Part 1: Technical Report, SD 77-AP-0076 (Rockwell International, July 15, 1977).

FIGURE 1

ORIGINAL PART
OF POOR QUALITY

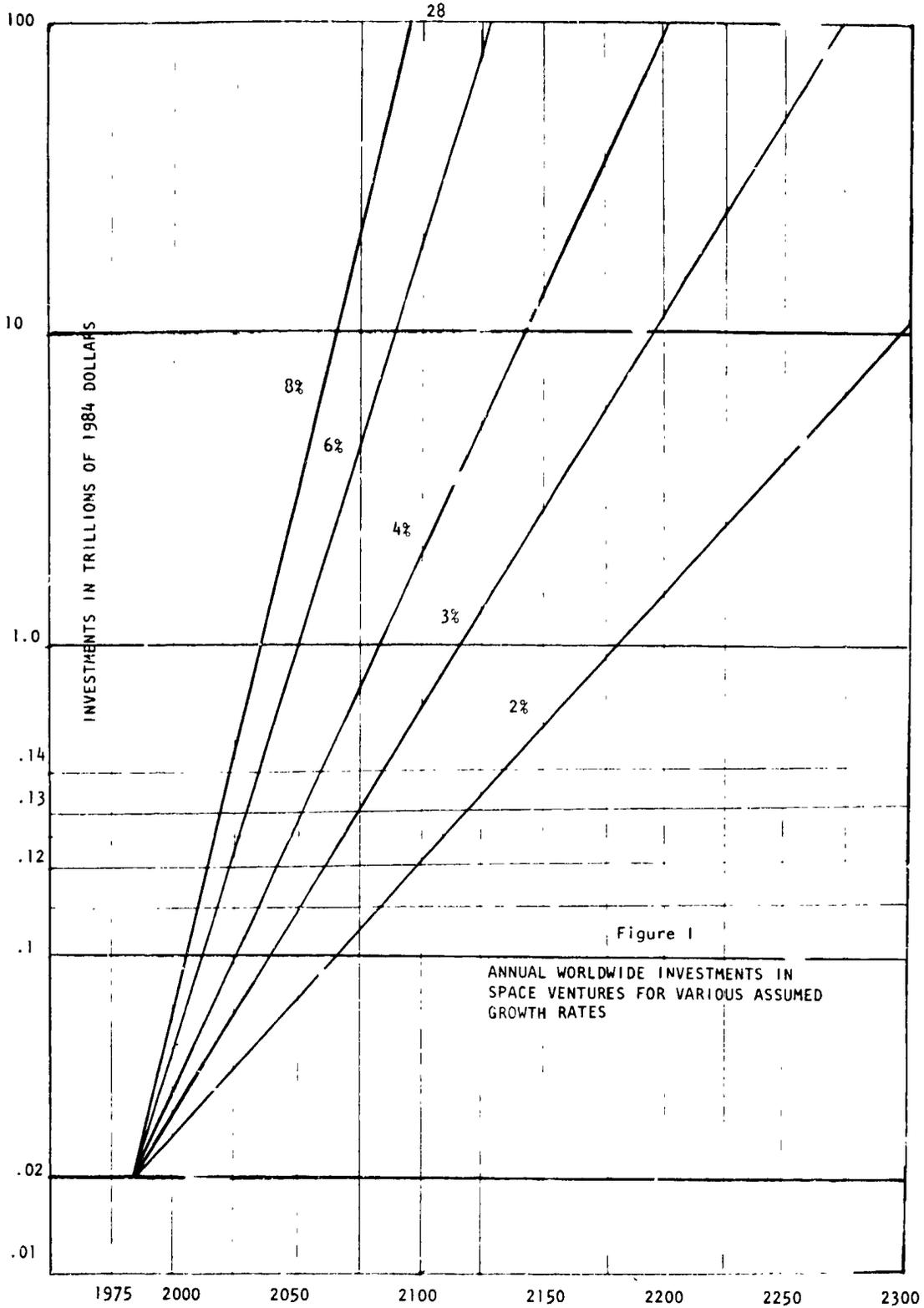


Table 4

PROGRESS IN SPACE TECHNOLOGY, PAST AND PROJECTED

SYSTEM	1960	1975	1990	2000
1. LAUNCH VEHICLE: PAYLOAD CAPACITY (LBS)	25	250,000	80,000 (REUSABLE)	500,000 (REUSABLE)
2. COMMUNICATION SATELLITE (CHANNELS)	15 (LEO)	15,000 (GEO)	100,000 (GEO)	10 ⁷ (GEO)
3. COMM. (MARS TO EARTH) BITS/SEC	8	10 ⁵	10 ⁷	10 ⁹
4. MIN DAYS/MISSION	.1	250	10 ⁵	5 x 10 ⁵
5. RESOLUTION (KM)	5 (LEO)	.1 (LEO)	.05 (GEO)	.02 (GEO)
6. DATA STORAGE ABOARD SPACECRAFT	15 PAGES	2,000 BOOKS (20 GIGABITS)	1/2 LIBRARY OF CONGRESS (8,000 GIGA- BITS)	10 LIB. OF CONGRESS
7. ENERGY STORAGE (KW HRS/LBS)	.02	40	800	1200
8. ACTIVE CIRCUITS/IN. ³	4	120,000	5 x 10 ⁸	10 ¹⁰ - 10 ¹²
9. SPACE-BORNE COMPUTER SPEED (OPERATIONS/SEC.)	.002 x 10 ⁶	.5 x 10 ⁶	30 x 10 ⁶	100-1000 x 10 ⁶
10. COST OF LAUNCHING (1975 \$/LB TO LEO)	10,000	1,500	500	200-300
11. POSITION ERROR (METERS)	1,000	50	.1	.02
12. FAILURES/HR/M. BITS/SEC	10 ⁻²	10 ⁻⁴	10 ⁻⁶	10 ⁻⁷ -10 ⁻⁸

THIS DATA IS ADAPTED FROM VARIOUS NASA SOURCES--PRIMARILY FROM THE REFERENCE GIVEN ON TABLE 3.

(SSPS) which could beam microwave power to earth in essentially unlimited quantities from the inexhaustible and constant sun. The microwaves are readily converted to electric power without polluting either air or water. At present the cost of power from an SSPS would not be competitive but it is possible that this could change during the next century.

The use of high vacuum in industries is rapidly growing, a trend which is almost certain to continue as high vacuum is required in nearly all electronics as well as many other high-tech enterprises. On earth providing and maintaining an adequate vacuum in industrial processes is expensive. In space, however, even very high vacuums unattainable on earth are trivially easy to arrange and can be "permanent."

Weightlessness may be the most interesting, and perhaps the most commercially important advantage available in space. It is the one continual property of every space orbit for which no parallel exists in daily human experience (beyond free fall which generally lasts less than one second). Space technologists are attempting to visualize the implications of the weightless environment and design processes which can exploit that advantage. Still this science and technology are presently at best embryonic, and likely to remain so throughout most of this century, even as they develop rapidly. Accordingly technology has a great potential in this field. Indeed there already exist some promises of exciting products and processes from orbiting industries.

Many materials behave differently when placed into a weightless environment. Liquids form perfect spheres which can be solidified, maintaining sphericity. Surface tension, usually a minor force compared to gravity can become the dominant one in space, making the contact zone between liquids and solids act in "peculiar" manners. Gases also behave differently. Hot air does not rise in zero-G, making it difficult to start a fire. A lit candle quickly snuffs itself out. Weightlessness means that structures a mile long can be made of thin metal foil without threatening to break or even to bend significantly. Tiny bearings can control massive rotors.

These and many other novel properties found only in space have spawned a large array of potential applications for SI, some of which can be expected to begin soon--perhaps by the early 1990s. The early efforts, naturally, will concentrate upon R&D. However, there are already some indications that production of high purity pharmaceuticals and of silicon wafers for electronic circuits are likely to be among the earliest commercial developments. A list of some of the more promising early SI technologies is given in Table 6.

Perhaps the key point in Table 5 is the tenth one--that the transportation costs to space and back have dropped rapidly and can be expected to decline further in the future. Indeed, as suggested in Table 4, about a factor of 2 to 10 in reduced transport costs may

Table 5TEN ADVANTAGES OF OPERATING IN SPACE

1. SOLAR POWER (10 x RATE ON EARTH) PLUS U-V, X-RAYS, ETC.
2. UNLIMITED HIGH VACUUM, (10^{-8} to 10^{-14} MM. SPACE HG. IN 300 MILE ORBIT)
3. AVOIDS MANY EARTH HAZARDS
 - STORMS (HURRICANES, TORNADOES, DUST, SNOW, HAIL, ICE, RAIN, WIND,...)
 - SPORADIC DANGERS (EARTHQUAKES, FLOODS, DROUGHTS, VOLCANOES, LIGHTNING,...)
 - UNPREDICTABLE TEMPERATURES & HUMIDITY (DAILY, SEASONAL...)
 - INTRUDERS (HUMAN, RODENTS, INSECTS, MICROBES,...)
 - ACCIDENTS (AUTO, DROWNING, FALLS,...)
 - OTHERS (CORROSION, POLLUTION)
4. WEIGHTLESSNESS FACILITATES
 - A. SPECIAL MANUFACTURING ACTIVITIES
 - B. CONSTRUCTION OF VERY LARGE DELICATE STRUCTURES
 - C. RELIABILITY OF OPERATIONS
5. POTENTIAL RAW MATERIALS ON MOON AND ASTEROIDS
6. GOOD "VIEWS" OF EARTH AND OUTER SPACE FOR COMMUNICATION, OBSERVATION, POWER TRANSMISSION, AND OTHER APPLICATIONS
7. INFINITE HEAT SINK NEAR ABSOLUTE ZERO
8. LITTLE OR NO ENVIRONMENTAL, ECOLOGICAL OR "LOCALISM" ISSUES
9. MAY BE ENJOYABLE, HEALTHFUL, STIMULATING OR OTHERWISE DESIRABLE
10. RAPIDLY IMPROVING TRANSPORTATION AND INCREASINGLY USEABLE AND AVAILABLE INFRASTRUCTURE

IN ANY CASE A TRUE FRONTIER

be possible soon after the end of the century. The more optimistic projection is based upon a rapid continued worldwide expansion in space activities, represented by expanding budgets and cooperative efforts. As transportation costs drop the number of viable SI products can increase rapidly--at least while transportation remains a dominant economic factor. With the Space Shuttle the cost of transportation to LEO in the early 1990s is expected to be about \$500 per pound (1975 dollars). That cost represents substantial progress but is still high enough to prevent the commercialization of many products. Also it will restrict many kinds of R&D, at least until a more advanced transportation system arrives.

For the long term future space transportation costs have been projected along three modes: optimistic, moderate and pessimistic. These projections are given in Figure 2. After 200 years the optimistic view projects a cost of \$.90/lb. to low-earth orbit, about 4 or 5 times the cost of the theoretical minimum energy requirement--based on current prices for electric power. The most conservative projection suggests about \$6/lb., only a factor of three better than what is believed to be technically feasible during the next 25 years. The actual path that space transportation costs follow may be the most important single technical factor affecting future space developments.

The number of human beings employed in SI facilities will, in turn, be strongly affected by transportation costs. The utilization of people in orbit requires the transport of housing facilities, food, air, water, and various paraphernalia for maintenance, communication, etc. As long as transportation remains relatively expensive the SI effort must depend upon a very high degree of automation, including the use of compact teleoperators for operations, maintenance and/or process changes. The paucity of human attendants will reduce operating flexibility substantially, but it will be a necessary phase of the evolving SI process.

C. Other Commercial Opportunities

An interesting study produced in the mid '70s by Bekey, Mayer, and Wolfe offered a large number of conceptual designs for new space concepts that might be commercially feasible during this century. A summary of their potential non military applications is given in Table 7.

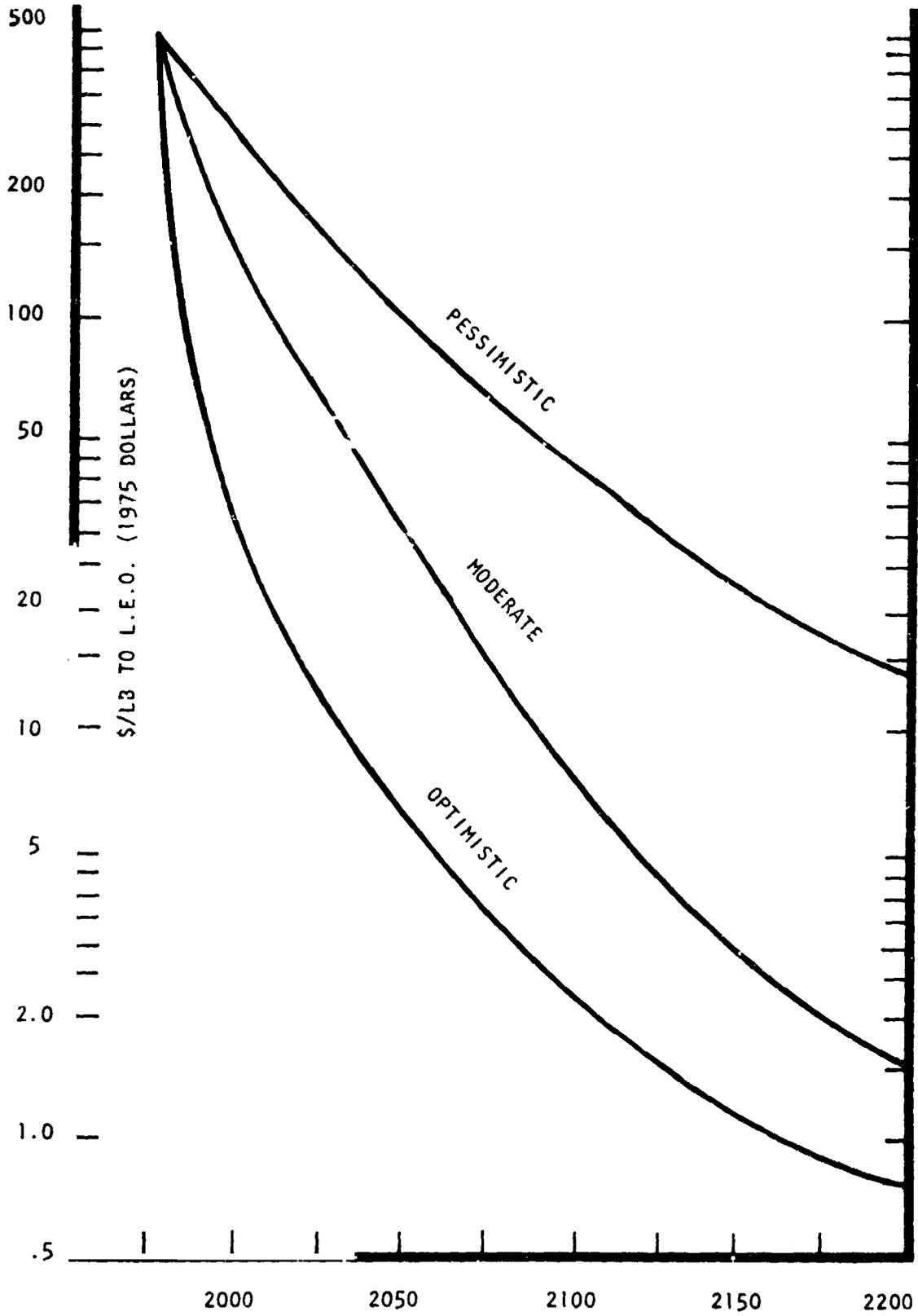
These concepts have been examined sufficiently to sketch out the engineering designs and to permit rough cost estimates to be made. Each concept was assigned a risk rating from I to IV (low to high) and a time frame for its first potential installation. Of the 42 initiatives given in their report, four have been selected for illustration and are presented below as Figures 3,4,5, and 6. The list of potentially practical space projects can be expected to grow steadily, perhaps even exponentially, if future funding of space development in the U.S. at least keeps pace with the G.N.P. If future space budgets are sufficient to permit the construction of an advanced transportation

Table 6A SUGGESTIVE, BUT HARDLY EXHAUSTIVE, LIST OF
SPACE MANUFACTURING ACTIVITIES

1. VACUUM CAST ALLOYS AND VACUUM WELDS
2. HIGH-PURITY BIOLOGICALS AND NOVEL PHARMACEUTICALS
3. OPTICAL SYSTEMS - PARTICULARLY FOR LOW G - AND THIN FILM SURFACES
4. LARGE ORBITING STRUCTURES (ANTENNAS, ENERGY SYSTEMS, SPACE STATIONS, ETC).
5. LARGE-SCALE VACUUM BASED SYSTEMS (E.G., CRYOGENIC, SUPER-CONDUCTING)
6. SPECIAL ELECTRONIC MATERIALS, INCLUDING PURE CRYSTALS
7. PROPULSION FUELS (AND SPACE CRAFT COMPONENTS) FOR FURTHER SPACE DEVELOPMENT
8. ULTRA HIGH STRENGTH FIBERS
9. PRODUCTS UTILIZING SPECIAL MINERAL FINDS: (E.G., WATER, TITANIUM, ALUMINUM)
10. POWER STATIONS FOR SOLAR ENERGY CONVERSION"
11. 3-DIMENSIONAL INTEGRATED-CIRCUIT CHIPS FORMED FROM ZERO VACUUM MELTS
12. DELICATE INSTRUMENTS FOR ZERO-G USE (WHICH COULD NOT STAND HIGH STRESSES OF EARTH FABRICATION AND/OR LAUNCH)

Figure 2

TRANSPORTATION COSTS TO NEAR-EARTH ORBIT



system which can deliver payloads to orbit at, say, \$50/lb. or less, then SI could develop dramatically. In such circumstances commercial space-based services and products are likely to look attractive enough to private investors to create a new "gold rush" of space initiatives not the least of which would be the space-tourism industry.

D. Future Space Program: Near Term

Any national space program must reconcile its many specific options with the available budget. NASA, which has been enduring a gradual budgetary squeeze for several years, has had to cut back and stretch out a number of its space programs despite an enviable record of successful launches and reasonably accurate cost projections. Nevertheless every space enthusiast hopes for a logical long-term space development program with at least a gradually, if not rapidly, increasing budget. One well-conceived and well-presented perspective on NASA's future program, for example, appeared several years ago in the Journal of the British Interplanetary Society. This paper describes an evolving program in considerable conceptual detail, a program which gradually expands Man's occupancy of space from near-earth orbit to the outer planets, developing the required transport, communication, manufacturing systems, and space colonies as they are needed. Many of the costs of associated 20th century subsystems were estimated, although the full required annual space budgets were not projected. However the concepts and schedules are roughly compatible with the early developments of the Optimistic Scenario and in part with the Moderate Scenario; these scenarios appear in subsequent sections.

Perhaps the most prolific designer of potential space industrial systems has been Dr. Krafft Ehrlicke of Rockwell International. An extensive review of Ehrlicke's contributions was made available a decade ago in Congressional Hearings entitled Future Space Programs 1975. Ehrlicke offered a "complete package" with philosophical justifications, original space-based concepts, transportation system requirements, engineering designs, and cost estimates. Many of his concepts have since affected NASA's programs. Many of them are explicitly or implicitly included in the developments indicated in the Optimistic Scenario. Many other excellent contributions by other space scientists can be found in the above reference that have provided considerable guidance to this study.

* Jesco von Puttkamer, "Developing Space Occupancy: Perspectives on NASA Future Space Programme Planning," Journal of the British Interplanetary Society 29 (1976): 147-173.

** U.S., Congress, House, Committee on Science and Technology, Future Space Programs 1975, A Compilation of Papers prepared for the Subcommittee on Space Science and Applications. 94th Cong., 1st sess., September 1975, Committee Print, 2: 59-65. (See, also, footnote on p. 74.)

ORIGINAL
OF FOUR

Table 7

NEAR TERM POTENTIAL SPACE APPLICATIONS
(SUMMARY AND RISK ESTIMATION)

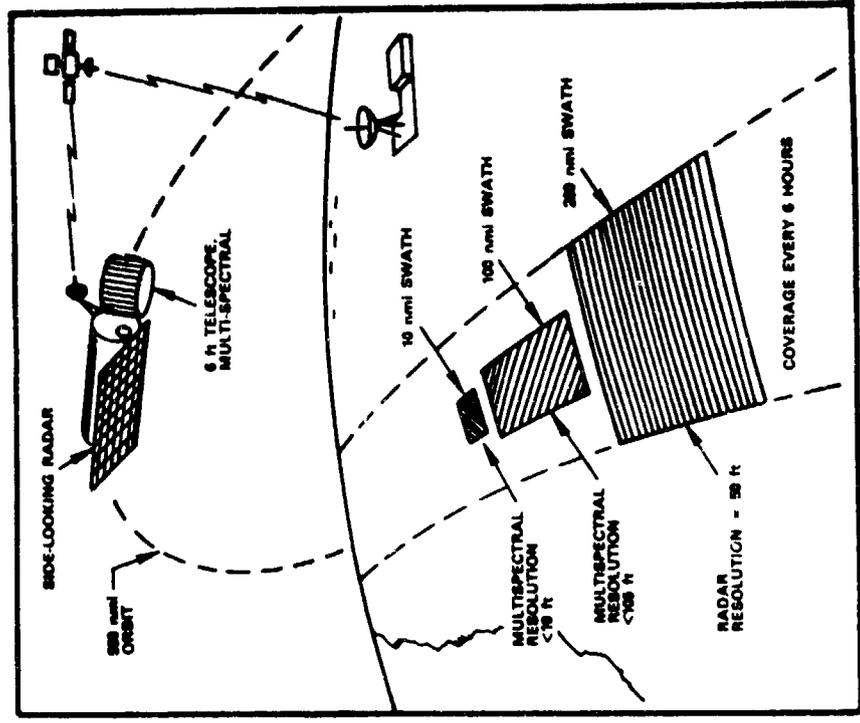
	RISK CATEGORY*		RISK CATEGORY*
<u>PERSONAL APPLICATIONS</u>		<u>GOVERNMENT APPLICATIONS</u>	
- Personal Communications Wrist Radio	I	<u>COMMUNICATIONS</u>	
- Emergency/Rescue Wrist Beacon	I	- Voting/Polling Wrist Set	I
- Personal Navigation Wrist Set	II	- Electronic Mail Transmission	I
- Voting/Polling Wrist Set	I	- Border Surveillance	II
<u>CIVIC APPLICATIONS</u>		- Nuclear Material Locator	I
- Disaster Communications Wrist Radio	I	- Library Data Sharing	I
- All-Aircraft Traffic Control	I	<u>OBSERVATION</u>	
- Urban/Police Wrist Radio	I	- High Resolution Resources/Pollution Observatory	II
- Car Speed-Limit Control	I	- Water Level and Fault Movement Indicator	I
<u>INDUSTRIAL APPLICATIONS</u>		- Atmospheric Temperature Profile Sounder	III
- Burglar Alarm/Intrusion Detection	I	- Forest Fire Detection	I
- Vehicle / Package Locator	II	- Ocean Resources Location	I
- 3D Holographic Teleconferencing	III	<u>SUPPORT</u>	
- Advanced T.V. Broadcast	I	- Passive Coastal Anti-Collision Radar	II
- Advanced Resources/Pollution Observation	I	- Night Illuminator	II
<u>INTERNATIONAL APPLICATIONS</u>		- Energy Delivery and Distribution (5 concepts)	IV
- Nation-to-Nation "Hot Lines"	I	- Energy Consumption Monitor	I
- Multinational Air Traffic Control Radar	I	- Aircraft Laser Beam Powering	IV
- Small Terminal Inmarsat Network	I	- Nuclear Waste Disposal	II
- Earth Resources Data Sharing	I	<u>SCIENTIFIC APPLICATIONS</u>	
- Energy Distribution Relay	IV	- Astronomical Super-Telescope	IV
- U. N. Truce Observation Satellite	I	- Interplanetary T. V. Link	II
		- Atmospheric Temperature Profile Sounder	III
		- Ocean Resources and Dynamics Sensor	I
		- Water Level and Fault Movement Indicator	I

* I-IV ARE LOW TO HIGH, RESPECTIVELY.

SOURCE: I. BEKEY, H.L. MAYER AND M.G. WOLFE, ADVANCED SPACE SYSTEM CONCEPTS AND THEIR ORBITAL SUPPORT NEEDS (1980-2000), VOLUME I: EXECUTIVE SUMMARY, ATR-76(7365)-1, VOL. I (EL SEGUNDO, CALIFORNIA: THE AEROSPACE CORPORATION, APRIL 1976), P. 27.

ADVANCED RESOURCES / POLLUTION OBSERVATORY (CO-1)

Figure 3

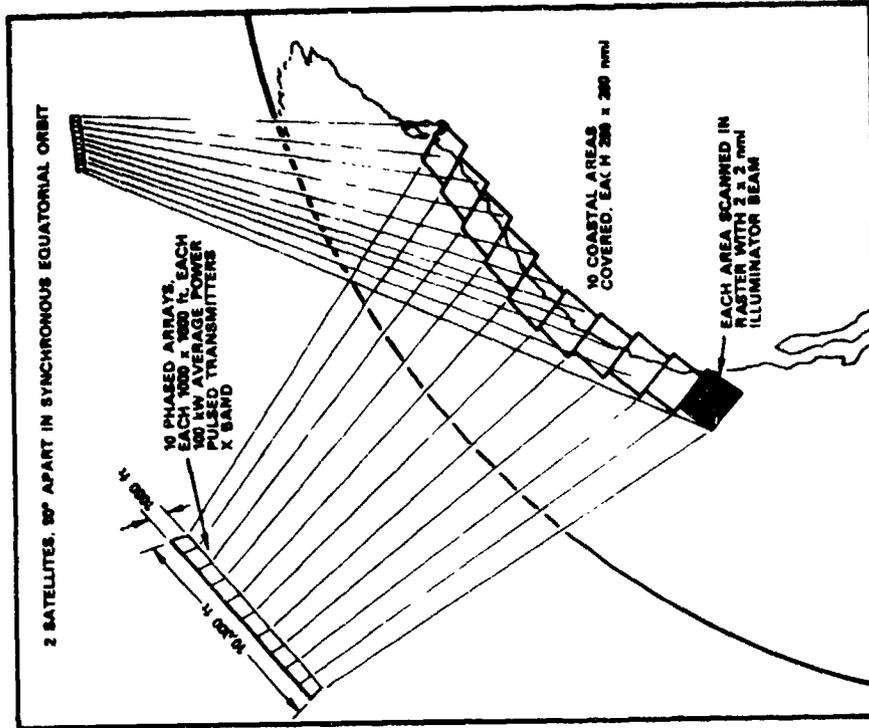


- **PURPOSE**
To provide high quality, multi-spectral earth resources and pollution data.
- **RATIONALE**
Integrated ERTS-like system, real-time data distribution to worldwide users, active sensors needed.
- **CONCEPT DESCRIPTION**
Active and passive sensors, large aperture, high, medium, and low resolution imaging obtained in multi-spectral region and radar. Data disseminated by laser link through relay satellite.
- **CHARACTERISTICS**
 - **WEIGHT**
30,000 lb
 - **SIZE**
10 x 60 ft
 - **RAW POWER**
12 kW
 - **ORBIT**
500 nmi sun synch.
 - **CONSTELLATION SIZE**
1
 - **RISK CATEGORY**
I (Low)
 - **TIME FRAME**
1985
 - **ICC COST (Space only)**
350 M
- **PERFORMANCE**
Multi-spectral resolutions varying from <math>< 10</math> to <math>< 100</math> ft obtained worldwide.
- **BUILDING BLOCK REQUIREMENTS**
 - **TRANSPORTATION**
Shuttle and tug
 - **ON-ORBIT OPERATIONS**
Shuttle attached manipulator, servicing stages
 - **SUBSYSTEMS**
Guidance and navigation; attitude control; transmitter
 - **TECHNOLOGY**
Large radar antenna; high power tubes and modulator; LSI data processor
 - **OTHER**
None

SOURCE: I. BEKEY, H.L. MAYER AND M.G. WOLFE, ADVANCED SPACE SYSTEM CONCEPTS AND THEIR ORBITAL SUPPORT NEEDS (1980-2000), VOLUME III: DETAILED DATA - PART I: CATALOG OF INITIATIVES, FUNCTIONAL OPTIONS, AND FUTURE ENVIRONMENTS AND GOALS, ATR-76(7365)-1, VOL. III (EL SEGUNDO, CALIFORNIA: THE AEROSPACE CORPORATION, APRIL 1976), P. 10.

Figure 4

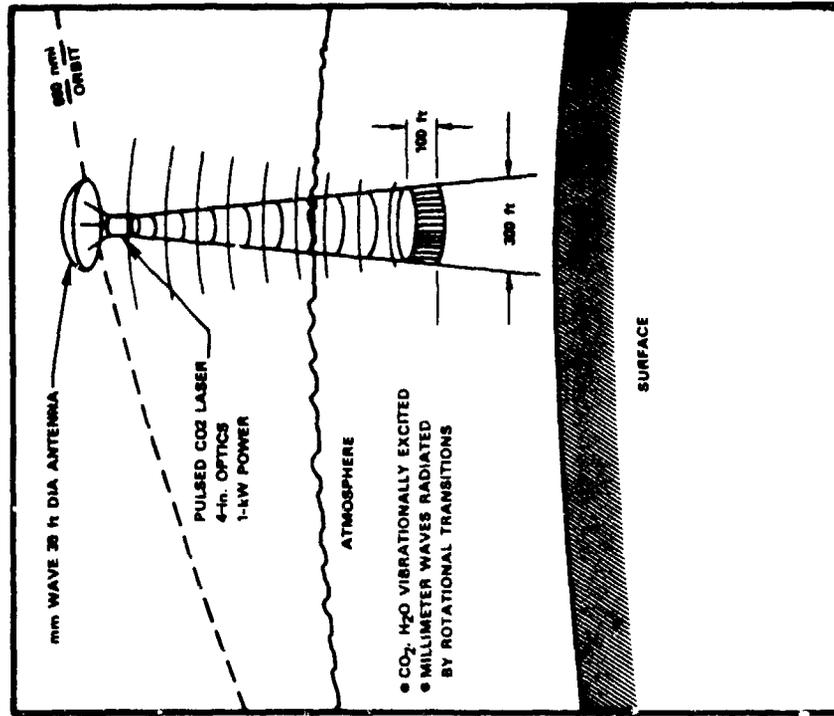
COASTAL ANTI-COLLISION PASSIVE RADAR (CO-9)



- **PURPOSE**
Inexpensive and lightweight radar for all surface vessels - navigation; collision avoidance.
- **RATIONALE**
Conventional radar too expensive and interference prone. Pleasure craft usually denied radar benefits.
- **CONCEPT DESCRIPTION**
Illuminate seacoasts with scanning microwave beams from space. Scanning receiving antennas on boats obtain range and angle data on hazards.
- **CHARACTERISTICS**
 - WEIGHT 2,000,000 lb
 - SIZE 1,000 x 10,000 ft
 - RAW POWER 3 MW
 - ORBIT Synch. Equat.
 - CONSTELLATION SIZE 2
 - RISK CATEGORY 11 (Medium)
 - TIME FRAME 1995
 - IOC COST 10 B
- **PERFORMANCE**
Relative location of all objects > 100 m² within 12 nmi range. 100 x 300 ft accuracy in 50° sector. 3 x 0.5 ft antenna in vessel. Unlimited number of users.
- **BUILDING BLOCK REQUIREMENTS**
 - TRANSPORTATION LLV and large tug or large SEPS
 - ON-ORBIT OPERATIONS Automated or manual servicing unit; assembly in orbit
 - SUBSYSTEMS Structures; attitude control; antenna; power
 - TECHNOLOGY Large adaptive microwave antenna; high power transmitters; prime power source.
 - OTHER

SOURCE: I. BEKEY, H.L. MAYER AND M.G. WOLFE, ADVANCED SPACE SYSTEM CONCEPTS AND THEIR ORBITAL SUPPORT NEEDS (1980-2000), VOLUME III: DETAILED DATA - PART I: CATALOG OF INITIATIVES, FUNCTIONAL OPTIONS, AND FUTURE ENVIRONMENTS AND GOALS, ATR-76(7365)-1, VOL. III (EL SEGUNDO, CALIFORNIA: THE AEROSPACE CORPORATION, APRIL 1976), P. 18.

ATMOSPHERIC TEMPERATURE PROFILE SOUNDER (CO-11)



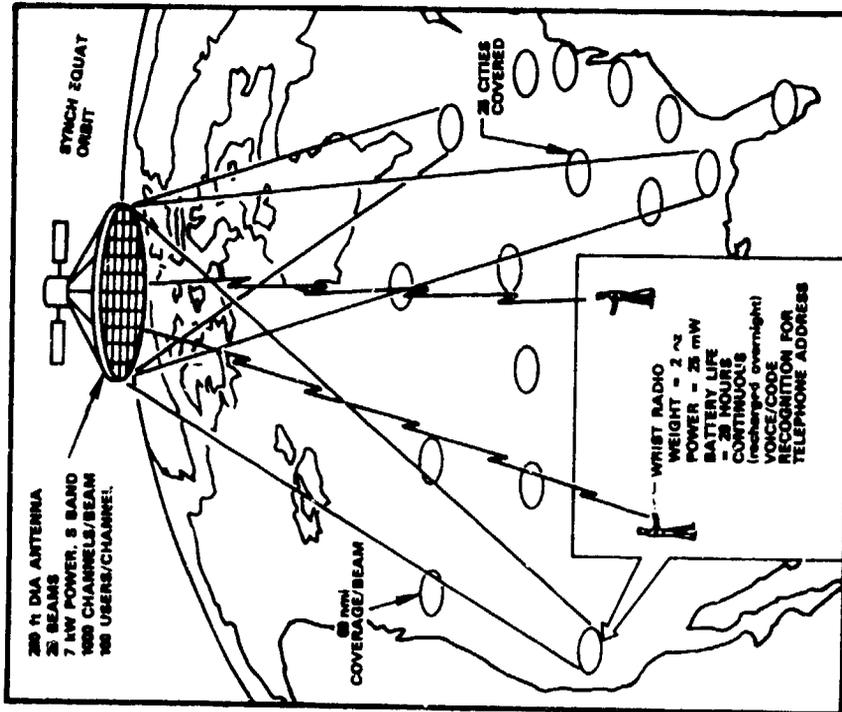
- **PURPOSE**
To measure actual profiles of temperature in the atmosphere.
- **RATIONALE**
Weather prediction requires knowledge of temperature profiles, as well as other phenomena.
- **CONCEPT DESCRIPTION**
Pulsed laser vibrationally excites CO₂ or H₂O molecules. Subsequent rotational transitions in the millimeter wave spectrum show temperature dependence which is measured by ratio of energy in several lines.
- **CHARACTERISTICS**
 - WEIGHT 4000 lb
 - SIZE 30-ft dia antenna
 - RAW POWER 5 kW
 - ORBIT 600-nmi polar
 - CONSTELLATION SIZE 4
 - RISK CATEGORY III (Medium)
 - TIME FRAME 1990
 - IOC COST (SPACE ONLY) 250 M
- **PERFORMANCE**
Entire atmosphere measured, with resolution of 300 ft horizontally and 100 ft vertically, every four hours. Emission lines and signal strength imprecisely defined at present.
- **BUILDING BLOCK REQUIREMENTS**
 - TRANSPORTATION Shuttle and tug/IUS
 - ON-ORBIT OPERATIONS Automated service unit/Shuttle-attached manipulator
 - SUBSYSTEMS Antenna, laser, attitude control
 - TECHNOLOGY Laser, power dissipation, antenna, pointing, sensitive heterodyne receiver
 - OTHER

SOURCE: I. BEKEY, H.L. MAYER AND M.G. WOLFE, ADVANCED SPACE SYSTEM CONCEPTS AND THEIR ORBITAL SUPPORT NEEDS (1980-2000), VOLUME III: DETAILED DATA - PART I: CATALOG OF INITIATIVES, FUNCTIONAL OPTIONS, AND FUTURE ENVIRONMENTS AND GOALS, ATR-76(7365)-1, VOL. III (EL SEGUNDO, CALIFORNIA: THE AEROSPACE CORPORATION, APRIL 1976), P. 20.

Figure 6

PERSONAL COMMUNICATIONS WRIST RADIO (CC-9)

- **PURPOSE**
To allow citizens to communicate through exchanges by voice, from anywhere.
- **RATIONALE**
Mobile telephones are desirable, but should be wrist worn. Uses include emergency, recreation, business, rescue, etc.
- **CONCEPT DESCRIPTION**
Multichannel switching satellite and wrist transmitter-receivers connect people anywhere to each other directly or to telephone networks. Analog or vocoded voice used.
- **CHARACTERISTICS**
 - WEIGHT 16,000
 - SIZE 200 ft antenna
 - RAW POWER 21 kW
 - ORBIT Synch. Equat.
 - CONSTELLATION SIZE 1
 - RISK CATEGORY I (Low)
 - TIME FRAME 1990
 - IOC COST (SPACE ONLY) 300M
- **PERFORMANCE**
25,000 simultaneous voice channels, each shared by up to 100 users; 2.5 million people communicate by normal voice.



- **BUILDING BLOCK REQUIREMENTS**
Shuttle and large/tandem tug or SEPS
Automated or manual servicing unit; assembly on orbit
Attitude control; antenna; processor; repeater
Large multibeam antenna; multi-channel repeater; LSI processor, multiple-access wrist transceiver, LSI technology
- **TRANSPORTATION**
- **ON-ORBIT OPERATIONS**
- **SUBSYSTEMS**
- **TECHNOLOGY**
- **OTHER**

SOURCE: I. BEKEY, H.L. MAYER AND M.G. WOLFE, ADVANCED SPACE SYSTEM CONCEPTS AND THEIR ORBITAL SUPPORT NEEDS (1980-2000), VOLUME III: DETAILED DATA - PART I: CATALOG OF INITIATIVES, FUNCTIONAL OPTIONS, AND FUTURE ENVIRONMENTS AND GOALS, ATR-76 (7365)-1, VOL. III (EL SEGUNDO, CALIFORNIA: THE AEROSPACE CORPORATION, APRIL 1976), P. 32.

Probably one of the most useful guides to the future U.S. Space program was given in NASA's Outlook for Space report.* This thorough 1975 study examined the technological options and the socio-political milieu in which NASA expected to operate over the balance of this century. Thus over the last decade NASA's program has been oriented heavily toward the space Shuttle, earth applications satellites and R&D for future space industrialization, a trend which will probably continue for several years. This does not imply that space science and exploration will be ignored, but that their share of the space budget has been and may remain under some stress--an experience which can be quite disturbing to their advocates when NASA's budget is not expanding.

Over the longer term, however, there appear to be a few major important factors which are likely to determine the nature and size of the worldwide space development effort. These are considered next.

E. Future Space Program: Long Term

The 5 major factors which appear likely to determine the pace of future space developments are listed in Table 8.

The first factor or "key" is that future space technology needs to be successful. The main specific item within that category is a sharp reduction in the costs of transporting humans and materials into orbit. As mentioned earlier many design engineers believe that straight-forward R&D could reduce transport costs by as much as a factor of 10 soon after the end of this century. This outcome requires no great breakthroughs in basic propulsion systems. It is based upon the use of hydrogen-oxygen engines, larger reusable vehicles, and evolving designs optimized through computer-aided analysis. The estimate of a factor of 10 would probably apply only to automated "freighters" whose acceleration would not be limited by the presence of human beings. During the balance of this century manned operations in space projects will probably be minimized. In any event for several decades the bulk of payloads sent into space probably will not be human ones.

The transport costs estimated above could be greatly reduced if and when a fuel such as metallic hydrogen becomes available or if practical techniques are developed to transmit high levels of power to ascending vehicles either from the ground or from space satellites. All of these developments are conjectural at present, but are at least hopeful.

Without going into detail about the other specific items on the technologies listed in Table 8 it is possible with considerable confidence to assert that the indicated developments are likely to be successful.

*National Aeronautics and Space Administration, Outlook for Space, SP-386 (Washington, D.C.: Scientific and Technical Information Office, January, 1976).

Recent history of space technology, indeed of high technology generally, supports this conclusion in addition to the fact that the path toward such solutions is now reasonably well understood. Space technologists are confident that the near-term goals can be met, but they cannot know whether the national desire to attain these technological goals will be sufficient to provide the funding. The space "freighter" or a VTOVL-SSTO-HLLV (translated: Vertical Take Off and Vertical Landing, Single Stage To Orbit, Heavy Lift Launch Vehicle) as indicated earlier, might require about \$10 billion just for the R&D. Such a large project requires a very large-scale launching program to be contemplated, else the capital invested could not be amortized without making launch costs prohibitive. Moreover the full array of vehicles required for an advanced space transportation system would need to include various space tugs and landers for transferring payloads to new orbits or to and from other planetary bodies. The landing systems will be required for those payloads which are to be delivered to and returned from planetary surfaces (the Moon, Mars, Asteroids,...). These additional vehicles generally would be much smaller and less costly than the freighter. Preliminary designs for many of them already exist.

Rapidly expanding space travel and tourism appears to be an inevitable consequence of the indicated technological developments. Once the costs of space launches have been sufficiently reduced, and safety sufficiently assured, the interest in space travel or tours undoubtedly will quickly lead to an accommodating industry. A commercial industry, initially, could cater only to the wealthy as a space tour even 25 or 30 years from now might cost roughly \$250,000 (1975 dollars) for a trip of a few days, or perhaps a week, in LEO. However, if transportation costs continue to fall and personal income continues to rise as projected, then space tourism, which should begin before the 21st century, could become a unique industry--one that appears to have a rapid growth potential for the full interval of this study; that is, for at least a 200 year period.

Indeed, the onset of a space-tourist industry would increase the demand for space vehicles and thereby help to reduce unit transportation costs. Increasing travel and tourism would create a need for other space facilities: hotels, hospitals, even convention centers and museums, eventually. As transport costs drop, tours will undoubtedly be extended to visit space industrial facilities, lunar installations, and space colonies--as they come into existence. Tours might become a few weeks long rather than a few days--especially while launch costs remain high enough to preclude most repeat visits.

The expected number of future space tourists is strongly scenario dependent. The projections offered in Figure 7 may be orienting--not because they are "correct" but because they indicate the vast differences that are possible between an optimistic and pessimistic future from a space development point of view. The huge spread between these projections are related mainly to two factors: the average per-capita income, worldwide, and the projected launch costs. In the Pessimistic Scenario

Table 8KEYS TO LONG-TERM OPTIMISM FOR DEVELOPMENTS IN SPACE

1. SUCCESSFUL TECHNOLOGY

DECLINING TRANSPORTATION COSTS TO NEAR-EARTH ORBIT
EFFICIENT ORBIT-TRANSFER VEHICLES
ORBITING SPACE BASES AND PROFITABLE SPACE INDUSTRIES
INCREASINGLY AND RELIABLE "INTELLIGENT" ROBOTS
LUNAR BASES AND COLONIES
PLANETARY SPACE STATIONS AND COLONIES

2. SPACE TRAVEL AND TOURISM

"INEXPENSIVE" SAFE TRANSPORT
SPACE HOTELS, HOSPITALS, CONVENTION CENTERS
EXCITING JOURNEYS

3. FAVORABLE HEALTH EXPECTATIONS

PHYSICAL--MENTAL--EMOTIONAL
LONGEVITY

4. ATTITUDES IN SOCIETY

INCREASING PRIVATE INVESTMENT
NATIONAL ENTHUSIASM
INTERNATIONAL COOPERATION AND PEACEFUL COMPETITION

5. QUALITY OF "FRONTIER-LIFE"

FAVORABLE SOCIAL DYNAMICS
BENIGN POLITICS
RAPID ECONOMIC GROWTH

only about .1 percent of the world's population annually would tour outer space, even after 200 years. In the Optimistic Scenario after about 150 years almost anyone with the desire can travel into space and more than 10 percent do so, annually. Indeed, after 2100, the many purposes of space travel probably makes the term, tour, inappropriate for that scenario.

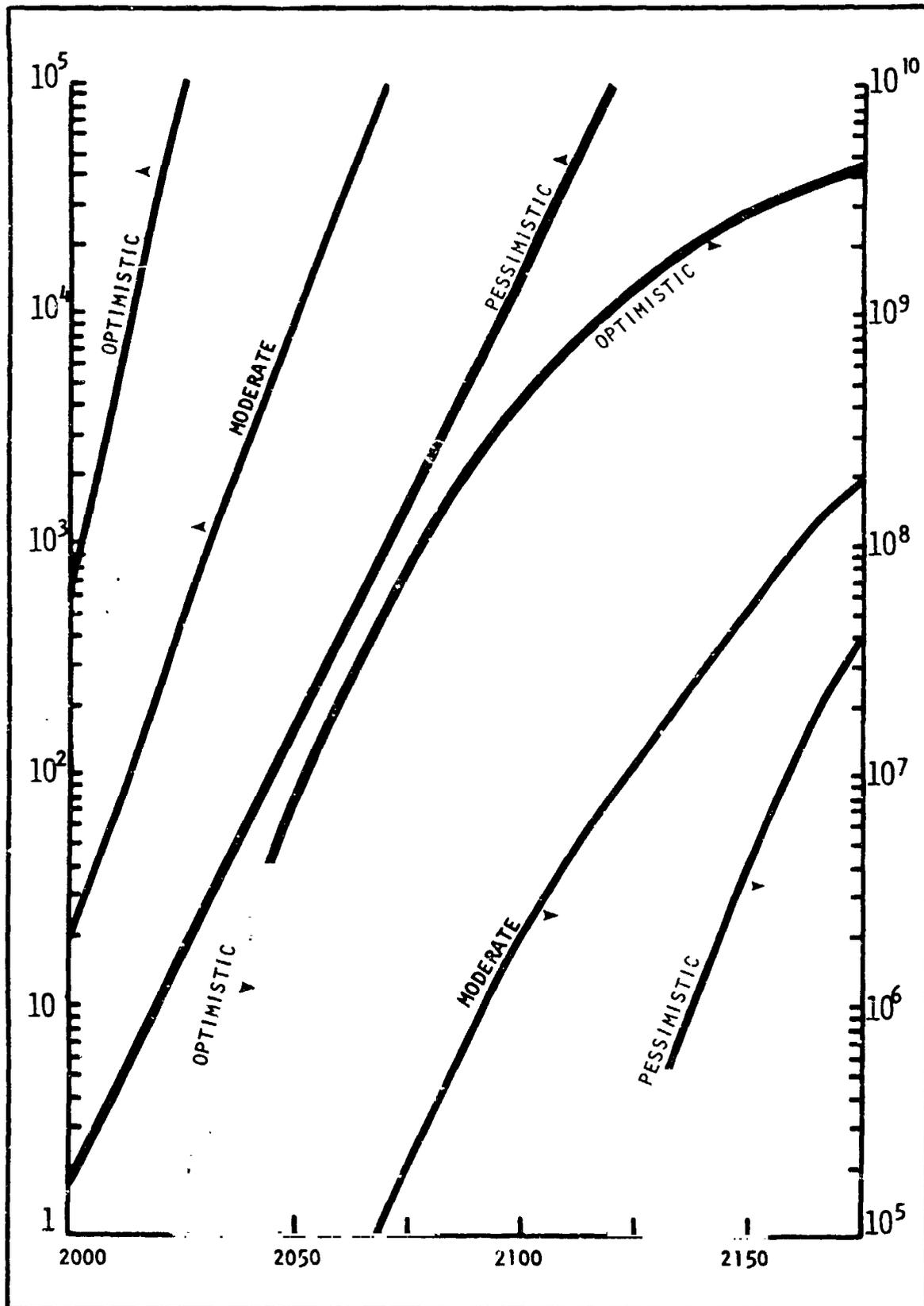
Perhaps the most critical of the "Keys" in Table 8 is that related to the health of human beings spending long periods of time in space; particularly for people who would live "permanently" in space colonies and, of course, for those born in space. Currently, so little is understood about potential health problems, and possible solutions to them, that no one can know whether living in space will, on balance, be beneficial or deleterious to a person's health. Even if the effect is small, the difference between a net health benefit and a net health deficit could be enormous for any future in which people "permanently" occupy space installations. If the net benefits are positive there might be no limit to the numbers of people who over time choose to live in space. If the net effect upon health is negative, then, except possibly for the attitudes of a relatively few eager space buffs, working or living in space would be interpreted by most people as requiring sacrifice. Clearly, that should entitle space-based employees to extra compensation but even so it is not likely to be attractive on a large scale--at least not after the novelty of living in space has worn off.

Undoubtedly the health aspects of living in space will have physical, mental and emotional components. A measurement of the total of these effects may, in fact, be very difficult. Suppose, for example, that the human body tends to become physically weaker and of different proportions, but that the mental capacity improves and the emotional reactions vary depending upon local space cultures and individual proclivities. How would these be "added" to give a net positive or negative result? Also, longevity might be different for those living in space. However, it is not unlikely that by the time substantial numbers of people are living in space--perhaps after 2025--that the average life expectancy on earth might by then have increased to 100 years, or more. In that case longevity in space might not become well established until sometime in the 22nd century, except possibly for the results of animal experiments--which might not be convincing.

During the next 50 years the life sciences are expected to experience a radical transformation, as they are in a state of "exploding" progress currently. Certainly, after that much time, much more accurate statements could be made about a person's state of health and of the probable effects of space travel or space living upon this state and upon the aging process. Whenever such assessments can reliably be made they could prove crucial to space developments requiring the long-term presence of many people. More optimistic long term projections should specifically assume at least small net health and/or longevity benefits: in relatively pessimistic projections the assumed health effects would at best be uncertain.

Figure 7

SPACE TOURISTS/YEAR



The fourth key to space development is related to various driving forces of earth societies. These are on three levels. First, commercial space activities must be profitable. Whether financed by private investors, quasi-public institutions, or governments, they will have to become profitable if they are to receive the continuing large infusions of capital required for long term growth. For prolonged rapid growth the required capital flow can become enormous; as can the annual value of space production. The potential growing disparity among the results for three scenarios is illustrated by the projections of Table 9.

These results quickly become mind-boggling numbers, especially those of the Optimistic Scenario. But after 200 years, even the end result of the Pessimistic Scenario might leave today's space agencies at a loss for projects on which to spend such funds. Moreover, because of probable technological advances an investment should buy much more after 200 years than it would today. Transportation costs alone are expected to decrease greatly, by about a factor of 30 even in the Pessimistic case.

The second driving force is national enthusiasm. Whether or not the profitable commercialization of space is rapid, many aspects of space exploration and development are known to be extremely important for basic sciences. In addition, many valuable spinoffs from technological development must be anticipated as well as new services to society. National pride in such accomplishments will be a significant factor. It probably accounts for much of the current wave of interest in both the reality of space ventures and space-oriented fiction that in the U.S. is being expressed through books, periodicals, movies, and television. A growing national interest and pride in space accomplishments will be required if public funding of these activities is to increase over time in real terms. Prolonged national enthusiasm appears to be a prerequisite for an optimistic outcome.

Finally, and potentially of great importance over the long term, is a requirement for a degree of international cooperation. Space development will be very expensive, at least for the next several decades. Without cooperation each interested nation would have to depend on its own resources, a path which would effectively prevent most of them from participating strongly and which also would impede those which do.

Competition is often desirable in many enterprises on earth. Cooperation may tend toward a stagnating bureaucratic monopoly. However, for space development that outcome for cooperation appears unlikely for at least many decades. The value of cooperative efforts has been demonstrated by the creation of ESA (European Space Agency) and by its joint venture with NASA in The Spacelab program. Moreover, without a measure of international cooperation the persistence of competition, growing competition among nations, could lead to unduly great difficulties in resolving potential conflicts of interest in many extraterrestrial regions.

Table 9

PROJECTED ANNUAL INVESTMENTS AND
PRODUCTION IN SPACE

(\$ TRILLION)

		2000	2025	2050	2076	2100	2125	2150	2176
#1 PESSIMISTIC SCENARIO	B	.015	.045	.075	.14	.20	.30	.4	.5
	P	-	-	.003	.01	.03	.10	.3	.5
	T	.015	.045	.078	.15	.23	.40	.7	1.0
#2 MODERATE SCENARIO	B	.03	.11	.35	0.7	1.2	2	2.8	3
	P	-	.01	.05	0.2	.4	1	2.8	6
	T	.03	.12	.40	0.9	1.6	3	5.6	9
#3 OPTIMISTIC SCENARIO	B	.10	1.0	5	20	50	90	200	500
	P	.02	.4	4	30	180	900	3,600	12,000
	T	.12	1.4	9	50	230	990	3,800	12,500

B = BUDGETS AND PRIVATE INVESTMENT

P = ANNUAL ECONOMIC PRODUCTION, IN SPACE

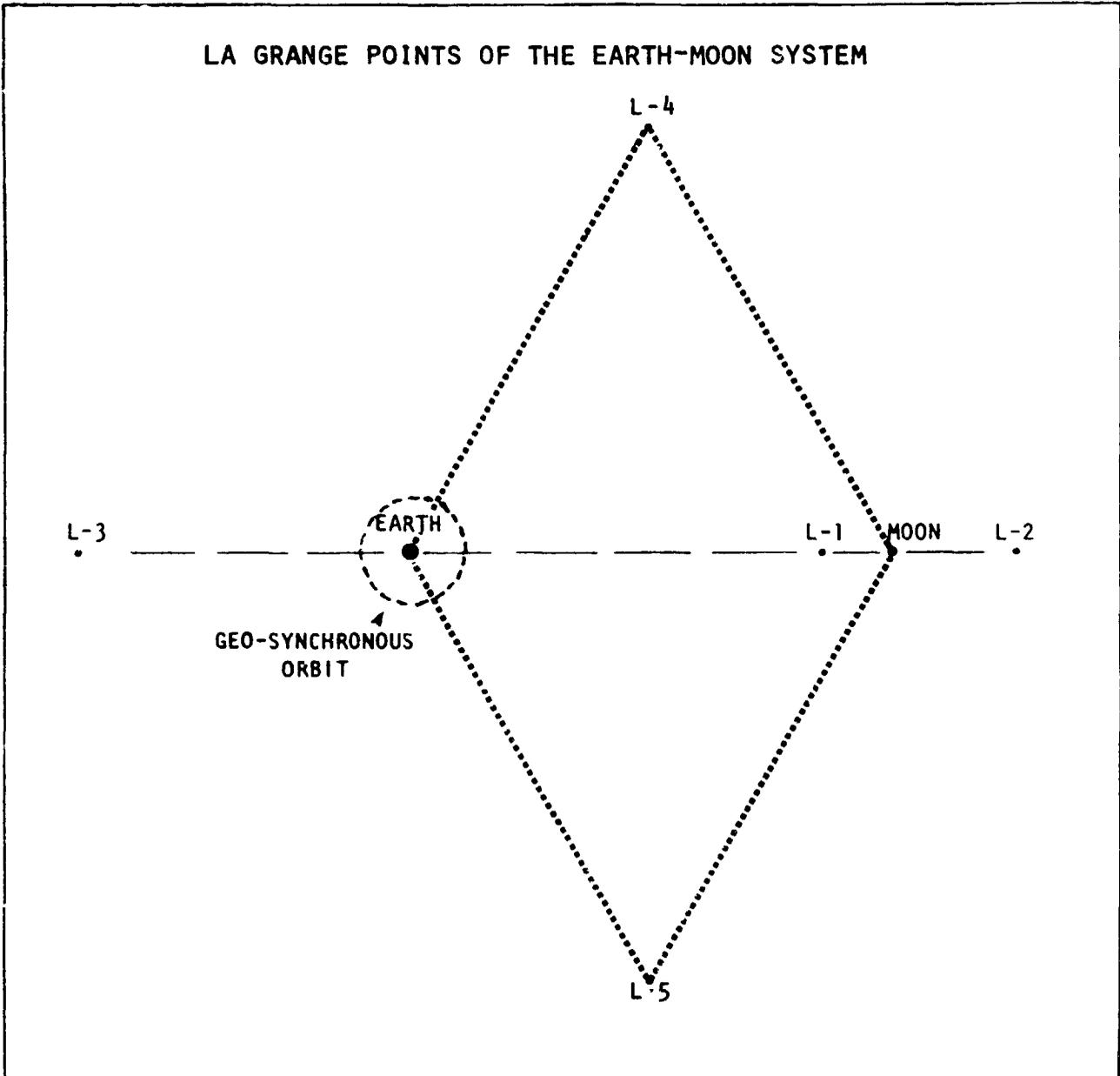
T = TOTAL, (B + P)

Eventually unresolved questions of who owns or has prior rights to certain preferred regions of space could become a persistent irritant to international relations. All of the preferred regions of space are not yet known, but we can guess at a few. For example, at least four of the five La Grange points are of potentially very special importance because they are the only stable space points in cis-lunar space (stable with respect to the earth-moon axis--see Figure 8). The four points are L_1 , L_2 , L_4 , and L_5 (L_3 is omitted only because it seems that no one has yet conceived⁵ of a special use for it). Other special points or regions would be the poles of the moon where nearly perpetual sunlight might be available and where water is most likely to be found in nearby craters; and perhaps the moon's "equator" (the line around the moon's surface which lies in the plane of the moon's orbit about the earth). Perhaps the most important region for the near-term is the earth's unique Geosynchronous Orbit. This is a circle with about a 160,000 mile circumference that might become crowded within a few decades. Can segments of this circle be claimed as national rights? Yes, they already have been!

Perhaps a matter of even greater importance would be the need to feel that over the long term non-military space installations and satellites would be safe from military threats. Orbiting manned space stations crossing over enemy territory during periods of imminent or overt hostilities might become particularly stressful places to be "trapped" in--especially if any deliberate damage to space satellites had already occurred. While space warfare might be preferable to terrestrial warfare, the possibility can only create an atmosphere restrictive to peaceful developments in space--especially, to manned space installations.

One specific area in which international cooperation or space law should soon become very important is related to space debris. The tendency to assume that space outside the earth's envelope is so large that man-made debris may be ignored has limits. Natural processes will always provide free cleaning services to some extent. For example, gaseous emissions are swept away by the solar wind when not otherwise captured by atmospheric envelopes. Objects orbiting within 250 miles of the earth's surface generally will be captured in less than a decade, or perhaps much less, the time depending on the geometry of the orbits and the sizes and shapes of the objects. Perhaps the most dangerous kinds of debris are those of small but greater than microscopic size--e.g., orbiting remnants of explosive bolts or small bits of debris produced by random collisions among uncollected orbiting objects. These bits of millimeter- or centimeter-sized objects might accumulate to dangerous proportions in long-lived orbits if their formation is not effectively prohibited by appropriate space law. The contemplated future transport of raw materials from the lunar surface to various earth orbits must be accomplished without "leakage" especially if, as has been visualized by O'Neill and others, the raw materials are to be catapulted into

Figure 8



space and subsequently collected.* It is not too early to attempt to visualize the kinds of space debris which might become dangerous and to devise ways to ameliorate the potential threat. Certainly the principle of keeping space--especially cis-lunar space--safe from collision with man-made debris must soon become an essential part of space ethics.

Thus, although it appears that a substantial amount of international cooperation in developing space would be rewarding for all concerned, history alone would suggest that such cooperation would at best be temporary. But history itself is not a completely reliable guide to the degree of future international cooperation or its effect upon space developments. However, history has demonstrated that competing nations are often willing to make great sacrifices. Then, and often only then, have the pressures become great enough to cut red tape, to accelerate their programs, and to take the risks required to prevail. Cooperative ventures, on the other hand, usually need to achieve a continuing consensus. A nation might be reluctant to spend more than (or even as much as) its original commitment, if there is an overrun or change of plan, and much haggling may occur over appropriate sharing. Furthermore, no single nation may get the bulk of the credit for a successful outcome and the psychological potential for exhilaration tends to be diminished.

The above characterization of a cooperative effort is often but not always true. Cooperation can boost morale when it creates important results that people approve of. One can imagine, for example, a very large multi-national effort to build a cooperative lunar facility that is enthusiastically supported by the participants, even while some other space exploration efforts remain competitive. A cooperative lunar project could also exist during an ongoing competition for leadership in space exploration or in earth-orbiting space manufacturing facilities. Thus, future space programs might achieve many of the advantages of both cooperation and competition. Of course, the particularly useful cooperative projects would be those which might not otherwise be feasible.

It might also turn out that cooperation in large space projects helps to resolve some conflicts on earth, perhaps because it refocuses attention on other important areas; but to expect this outcome may be wishful thinking. In the Moderate Scenario discussed later a lunar venture in a cooperative context provides unexpected benefits that surprise the original supporters of the venture.

It is also important to distinguish between minimal passive cooperation and high levels of active cooperation. A tacit agreement to avoid violence in space illustrates a minimum level of passive cooperation which should be relatively easy to achieve. Investing huge sums in a joint lunar space station would be a high level of active cooperation.

* Gerard K. O'Neill, The High Frontier: Human Colonies in Space (New York: William Morrow and Company, Inc., 1977).

Hostile competition or even the potential for war can sometimes be conducive to space developments. Certainly, this has been true in the past (e.g., ballistic missiles, anti-missiles, reconnaissance satellites,...). In the future one can at least imagine, for example, a protracted war restricted to battles in space. In this circumstance if both (or all) sides are making "all-out" efforts to win, their efforts would be accompanied by mobilizations to acquire the maximum capability for exploiting the militarily useful resources of space. By way of analogy, much historical exploration and development has been motivated by the search for military bases abroad and their associated strategic considerations (see Appendix B). Thus it seems possible that space development might, paradoxically, be the recipient of future benefits from either excellent cooperation or vigorous competition.

The last of the 5 "keys" appears to be the most difficult to analyze. It is related to the possibility of evolving and expanding space cultures--people organized into "societies" living in space. Initially, such societies may have fewer than 10 people, and eventually could grow to 100,000 or more. The social and psychological effects of prolonged living in space in any of a variety of habitats, none of which is presently well understood even in physical terms, will have to be discovered through experience. It is not at all clear that special preparations or selection processes can be devised on earth which would assure the viability of such social systems in space. If such societies grow very large then they are likely to develop internal political systems whose nature could be completely foreign to our past experiences.

Little more than great uncertainty now exists in any conjectures about future processes of making psychological, social, or political adjustments to life in space. Whether learning can effectively be transferred from any troubled society to another, or to its own successor, in order to improve future prospects for all--or indeed whether any such societies in space, troubled or not, will actually emerge in any important sense--appears to be almost completely a matter of conjecture.

A "solution" contemplated by O'Neill for large space colonies to be located near the L-5 La Grange point was to construct them so that they appear and feel almost identical with the earth environment--at least during a normal social mode--complete with wind, rivers, clouds, trees, animals, plants, houses, and with the earth's gravity. Whether this would be desirable or even feasible cannot be known for sure. It is an interesting and "conservative," but horrendously expensive, concept which like any other would have to endure thorough reality testing.

Any "solution," of course, would also have to be sustained through a period of assumed rapid growth. If such societies are viable, then over time they could be expected to increase in size and number, perhaps

*Gerald O'Neill, The High Frontier.

rapidly. Based upon past experiences this expansion process alone could be expected to bring additional socio-political challenges, the satisfactory resolution of which would have to evolve relatively peacefully.

The hypothetical societal problems presented here appear to be quite beyond the "primitive" analytical powers that exist today. This study will simply assume that acceptable solutions or resolutions are possible, postulating lesser or greater degrees of difficulty according to rather arbitrary standards. Naturally, in the most optimistic scenario any such problems will be overcome with the least difficulty.

CHAPTER III

OPTIMISTIC SCENARIO

PART I: THE TRIUMPH OF THE MACHINE? (1976-2000)

A. The Explosion of Technology

Although it was not easy for political leaders in the developed countries to realize it during the 1970s, in part because of the economic shocks (inflation, energy crisis, unemployment, material shortages, food shortages, etc.), individual technologists were becoming aware of the very rapidly growing analytical and industrial power in their own fields--although they may not have been too aware of the parallels in other areas of science and technology.

The last to understand the new phenomenon were the members of the shrinking New Class. Its influence in the developed countries had peaked in the late '70s and subsequently faded to insignificance over the next two decades. By 1990 many of its earlier goals had become generally accepted by society (e.g. clean air and water, seatbelts, resistance to nuclear power) but many of the remaining goals involved too much faddism, litigation and harassment (solar-power worship, extremism in safety, ecology, etc.) for the ideology to remain influential. Perhaps the major reason for the decline of the New Class was a growing public awareness that even modestly competent management, with help from innovative technology that free societies can create and develop into commercial systems, could provide economic growth and a generally-improving (but never ideal) quality of life--as measured by accepted reasonable criteria for health, safety and environmental purity. The futurologists of the late 20th century had become fully aware of the knowledge explosion, which according to their popular lore "started" in the '60s (actually it was the early '50s), and which became popular intellectual terminology in the decade of the '70s. But then, because of a natural lag between new knowledge and its widespread application, the felt tide of innovative technology--with several important exceptions such as rockets, lasers and micro-computers--was not to become widely apparent until around 1980. It has been an endless crescendo ever since.

The early technological groundswell was greatly aided by a sequence of magnificent inventions and developments in basic sciences, electronics, photonics, communications, lasers, space exploration, and a growing array of powerful new scientific instruments. Nearly all of the rapid progress in technology, in one way or another, usually quite directly and impressively, was related to the remarkable progress in solid-state electronic computers. During the amazing sequence of computer developments each advanced design was itself assisted by the previous generation of computers in a scientific marvel of "bootstrapping."

*See Appendix A for a definition and discussion of the New Class.

B. The Early Space Program in the U.S.

Budgets for the U.S. space program after the brilliant Apollo moon landings (which, were it not for the exceptional progress in computers during the early 1960s, could easily have resulted in disaster and aborted the space effort) nevertheless declined steadily to a new low just as the Space Shuttle became operational in the early 1980s. In 1980, for example, NASA's \$3.7 billion budget (in 1975 dollars) was close to its lowest level since the lunar landing. The government's (that is, the public's) inability to appreciate the future potential of the space program had led to a wait-and-see attitude--while Congress allowed the inflation of the 1970s to erode NASA's programs. The budget history for the U.S. and NASA during that era is given in Table 10.

Although this budgetary wrinkle in U.S. space program history was to be subsequently regretted, in the sense of opportunities lost through budget constraints, evidently it also helped to set up the psychological basis from which emerged a nearly exponential growth in space over the following 100 years, and probably also for many more years to come.

The technological heart of any space project, naturally, was the electronic computer. In an early study NASA had concluded and then stated quite clearly:

Without the speed and accuracy of automated data handling the space ventures...would be neither practical nor possible. Use of the computer now pervades all NASA activities, so much so that it is surprising that its necessity was not foreseen in most of the science fiction written about lunar and planetary exploration before it actually began.

This insight together with the near certainty of continuing rapid increases in the power of computers and instruments meant to NASA that applied scientific and technological progress was "exploding". Indeed, those who looked carefully also saw that basic theoretical sciences must also develop with continuously increasing rapidity. An immense (and rapidly growing) problem solving capability, with a competence that previously could hardly have been suspected except by a few avant-garde technophiles, was being extruded into reality by the improving sciences, the new automated instruments, and the leverage provided by the amazing computers. With these tools the technological community was poised to create a set of closely integrated technological marvels, some of the greatest of which were to occur in the development of space--in its science, exploration, earth applications, travel and industrialization.

* National Aeronautics and Space Administration, A Forecast of Space Technology, 1980-2000, SP-387 (Washington, D.C.: Scientific and Technical Information Office, January 1976). p. 3-3.

Table 10

FEDERAL BUDGET AND NASA APPROPRIATION, 1961-1984

FISCAL YEAR	TOTAL FEDERAL OUTLAYS*	NASA APPRO- PRIATION*	NASA APPROPRIATION (REAL YEAR DOLLARS)
1961	\$177,305	\$1,749	\$ 964
1962	190,299	3,251	1,825
1963	195,374	6,448	3,674
1964	204,887	8,816	5,100
1965	199,999	8,881	5,250
1966	220,464	8,481	5,175
1967	250,536	7,904	4,968
1968	271,474	6,004	4,589
1969	266,161	5,790	3,995
1970	269,116	5,157	3,749
1971	275,362	4,339	3,312
1972	290,174	4,164	3,310
1973	292,269	4,054	3,408
1974	294,427	3,323	3,040
1975	332,332	3,231	3,231
1976	353,378	3,376	3,552
1977	367,538	3,430	3,819
1978	383,616	3,399	4,064
1979	387,534	3,509	4,559
1980	416,612	3,696	5,243
1981	436,155	3,552	5,523
1982	452,321	3,598	5,932
1983	472,181	3,893	6,664
1984	479,656	3,969	7,048

*IN MILLIONS OF CONSTANT 1975 DOLLARS.

C. The Earth-Centered Context

As the stage was being set for a burst into space after the turn of the century there were a number of interesting developments "on the ground" that were to be "arranging the chairs." I mention a few of these here for orientation.

1. Energy Supplies

The conventional wisdom (i.e., the myth) of the early 1970s that the world was running out of energy--usable, relatively inexpensive energy--that so frightened the nations of the developed world at the time (and for a few years fed the fantasies of the leaders in OPEC)--had disappeared by 1994. It wasn't because energy self-sufficiency had been achieved in many countries. Rather, it was by then clearly apparent, even by former believers in the limits-to-growth philosophy, that immense reservoirs of energy were still available in natural gas, in coal, in shale, in uranium and thorium, in geothermal and solar sources, and even in conventional petroleum sources--the location and extraction of which had experienced a major revolution in a mere two decades. Also major contributions to energy costs and security were achieved through conservation in homes and buildings, by more efficient conversion of fuels to electric power, by the recovery of formerly wasted heat, and by new designs in industry and transportation for efficient utilization of energy. As a result most of the newly rich OPEC countries, deeply committed to internal industrial development programs found themselves with unforeseen worries. Market forces gradually reduced the price of oil to about \$10 per barrel, in 1975 dollars delivered in the U.S. The years 1980 to 2000 saw the development of inexpensive reliable solar cells and a myriad of ways of adapting them to autos, trucks, homes, buildings, factories, farms and central power stations--in addition to the obvious implication for their potential use in space transportation systems or for their application to space-based electricity generators which could even supply power to the earth, in the unlikely event that space would become a preferred source.

Also, the anti-nuclear-power movements of the '70s had diminished considerably by 1995 as the industry's ability to control the nuclear fuel cycle became very much improved technically and was effectively communicated to the public. New designs promised a steady improvement in the cost, reliability, efficiency and safety of fission reactors. Indeed, it was recognized that economics alone demanded this of fission reactors else they would be displaced by the improving cost-effectiveness of alternative power sources. (Also, by the late '90s the gaseous-core nuclear reactor had become the potential future champion of large engines for space power generation and orbital transfer vehicles that promised to be hard to beat. Still there was approaching competition from nuclear fusion engines to "worry about.")

Even though the economics of fusion power for earth-based systems was to remain in doubt for decades, great strides in that technology

"popped up" every year--seemingly out of nowhere, if one's information came only from news media sources. Thus the prospects remained exciting not only for competitive inexhaustible fusion power after 2020, but for highly efficient fusion-powered engines for space transportation soon afterwards.

These energy developments were somewhat depressing to commercial interests which had large investments in the solid fossil fuels. Although many technologies associated with these energy sources had also progressed--especially in-situ coal and shale conversion processes--their competitive prospects had dimmed by the year 2000. Still these technologies and the required solid fossil fuel resources would be available wherever they were needed during the next several decades and would facilitate the long-term transition to cleaner and essentially inexhaustible nuclear and solar energy supplies.

2. Resources

To a surprising extent the worried world of the 1970s had also come to believe that many non-energy resources--especially metals--were likely to be exhausted within a few decades. By 1995, despite a booming world economy, such images had virtually disappeared except as amusing anecdotes. In a mere 25 years technologically oriented efforts had:

- (1) doubled the estimated recoverable resources of most of the metals formerly considered to be on the verge of exhaustion such as copper, lead mercury and silver;
- (2) developed the technology for mining the seabed for nodules containing copper, nickel, and manganese in huge quantities;
- (3) developed "inexhaustible" alternatives for the major uses of silver, mercury, chromium, lead, zinc, and tungsten--at least for most of their anticipated commercial uses;
- (4) developed and demonstrated recycling systems that were soon to become 99 percent effective in recovering valuable metals from liquid wastes;
- (5) reduced the relative amount of metals required in industry by creating more efficient designs and steadily increasing the use of new plastics, ceramics, glasses, and composites as substitutes;
- (6) tested several new methods for extracting metals from sea water, some of which seemed almost certain to become economic early in the 21st century; and
- (7) used electronics to probe the lunar surface and a few asteroids with extraordinarily promising results for the 21st century

and beyond, when minerals from these sources would become useful to a burgeoning space industry.

3. Environment

Every developed and some developing countries made substantial progress in improving air and water quality during the '75-'95 period and, moreover, in many cases found commercial ways of changing wastes and pollutants into assets. For example:

- (1) Solid wastes were turned into foods, fuels, fertilizers, and mineral sources.
- (2) SO₂ emissions became a major source of commercial sulfur, sulfuric acid, gypsum and other useful materials.
- (3) Coal ash increasingly was used for road surfacing, and desirable land-fill projects.
- (4) While nuclear "wastes" were providing valuable isotopes for industrial uses and medical applications, processes to recover and return 99.99 percent of plutonium and other actinides from the nuclear power fuel cycle were developed and successfully tested.
- (5) Technologies for utilizing much of the formerly wasted heat from power stations and manufacturing plants were steadily progressing.
- (6) The recovery of low-level metallic wastes from effluents down to 1 ppm was soon to become routine in all important industries.
- (7) Biological "pesticides" were replacing chemical ones at an increasing rate, even as the latter were becoming much more efficient in selective targeting.

By 1995 the potential utility of most of these processes were still in their infancies and their future prospects were generally (and rightly) believed to be very bright. In the two decades before 1995 many people had envisioned the space program as one way to dispose of nuclear wastes; that is, to use space as an unlimited trash receptacle. Although this solution was possible, other approaches on earth were soon found to be much more feasible--especially those which turned those wastes into resources.

4. Food

Although the medium-term (2000-2025) prospects for adequate food supplies were generally perceived to be very bright, the shorter term

needs before the year 2000 were to remain marginal or dangerous for a few of the less-developed countries with massive populations that were dependent upon good weather and/or the good will of the food-exporting countries. Although their positions were not secure the situation was to improve more or less steadily after the early '80s. Moreover, most people in the world were coming to realize that, basically, the most important requirements for agricultural progress in the poorest countries were related to providing adequate incentives to farmers and protecting them from crippling taxes, price controls, and other regulations. Technical and economic assistance became readily available to needy regions and were effective where governments helped rather than hindered the flow and utilization of such assistance. As early as 1995 there were at least 30 models of developing countries that had been responsive to the emerging ethic--that external aid was available to all societies which were allowed by their governments to accept and employ it effectively.

Space-based systems played a growing role in nearly all of the above developments. This role was interesting, if somewhat obscure, during the '70s; but by the early '80s these systems were offering such valuable information to those institutions that were learning to utilize it that the number of customers for and applications of those programs increased at a rapid rate. Both private entrepreneurs and government soon realized that an interesting source of revenue was at hand and, as a result, the receipts from sales of information from satellite systems grew rapidly--as is shown by Figure 9 for the period 1970-2000. This income together with a growing demand for Space Shuttle services in the '80s contributed to the rapidly growing space budgets after 1987. By that time it had become quite clear that information from earth applications satellites was often a great bargain and therefore could be sold at substantially higher prices, where that was a desirable course either for the U.S. government or the blossoming space entrepreneurs.

D. Improved Space Vehicles

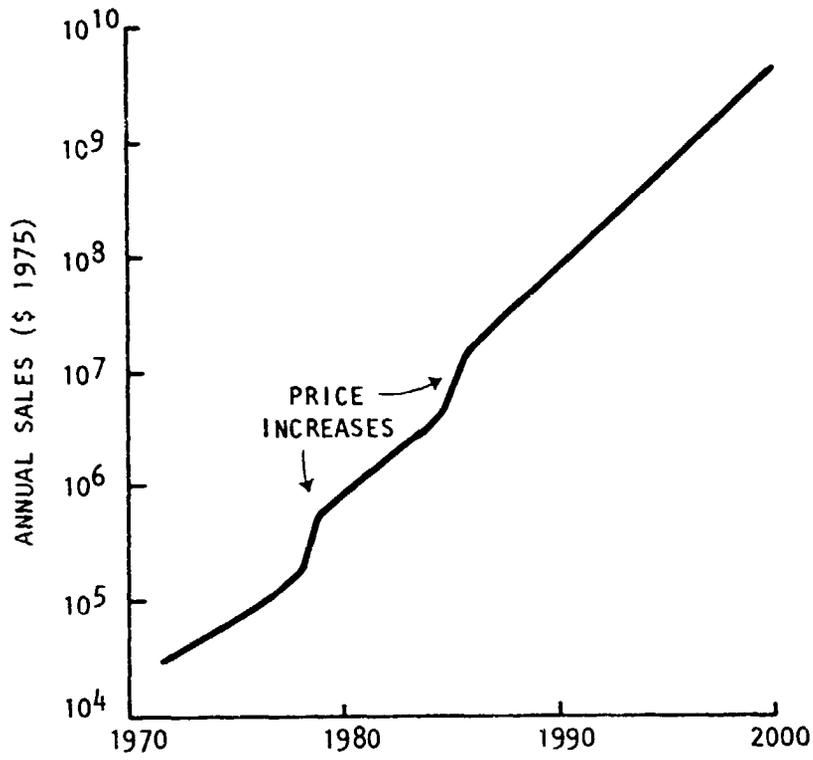
1. For Launch to Low-Earth Orbit (LEO)

Designs for advanced launch vehicles which could greatly reduce transport costs had been sketched since the early '60s and many of the promising alternatives were portrayed in NASA's 1975 Outlook for Space study. However, budget constraints forced NASA to postpone any serious large-scale effort until 1990. Nevertheless, enough of a useful technological base existed, thanks in part to the efficient use of computer-aided designs, that when a significant upturn in their budget first occurred in the late '80s NASA was quick to respond with projects for two major vehicles:

(1) The second-generation Shuttle Derived Launch Vehicle (SDLV) which became operational in 1996 and reduced transport costs initially by about a factor of 2.5 (to about \$300 per pound and--after further

Figure 9

COMMERCIAL SALES
OF SATELLITE DATA



improvements--to \$200 per pound in 2005. Also, after the year 2000 the SDLV became the primary vehicle taking travelers to space on a commercial basis.

(2) The 1/2-million-pound payload SSTO HLLV which became operational in 1998 and was soon delivering non-human payloads to space at \$100 per pound, and which (by 2008) was sending materials into space at the rate of 200 million pounds annually. (About half were U.S. payloads up to this point in time, but this fraction was to be gradually reduced as the space capabilities of other countries were increasing rapidly.) Indeed several countries (principally Japan, England, France, and Germany) had contributed substantially to the development of this vehicle and had worked out a cooperative arrangement with the U.S. for operating several of them from launching facilities in Europe and in Japan.

During the late '90s radical designs were being examined for new HLLVS which were destined to reduce launch costs (to \$35 per pound by 2025), in part because of the availability of metallic hydrogen as a fuel. The economics of space transportation in terms of the cost for launching inanimate objects into LEO for the 1976-2076 period--as well as the current projections to 2176--appear in Figure 2 (page 36). It must be remembered that the costs for human transportation, because of the G-restrictions and other required amenities, were to remain greater than average "freight" costs by factors ranging between 2 and 4.

2. Propulsion Systems for Orbital Transfer Vehicle (OTVs)

Before the Space Shuttle became fully operational in the early 1980s, the first vehicle considered for transporting satellites from LEO to more distant orbits was the Interim Upper Stage, a relatively inefficient system whose chief virtues were its reliability, its low cost to develop and manufacture, and its availability when the Shuttle became ready for routine use. However, the costs in using this OTV were relatively high; also, as it was fueled by solid propellants it was an inherently heavy non-reusable system. Therefore, before the Shuttle became operational NASA contractors had developed a modified orbital transfer vehicle, the Spinning Solid Upper Stage. This non-reusable vehicle was still encumbered with solid propellants but was considerably more efficient for many purposes. These two vehicles clearly constituted a stopgap arrangement for orbital transfers, mandated by the tight budgets of the '70s.

To complete the Space Transportation System (STS) many concepts and preliminary designs for the required new OTVs existed. These advanced "space tugs"--both manned and unmanned--only needed the caress of new funding to start a serious competition for the future STS. Concepts started to emerge from NASA's design divisions during the late '80s and by the end of the century an imposing array of new alternatives from the Solar Sail to the Advanced Fission Engine were available or in development (see Table 11).

E. Space industrialization

Prior to the Space Shuttle era one of the more difficult concepts for the public to accept as a coming reality was that of "floating factories" in space. Naturally, an earth-centered mind had difficulty envisioning a steel mill or copper smelter in orbit. This is quite understandable--particularly if one had visited any such installation on earth. However, the MISS (Made in a Space Station) concept had fascinated space technologists frequently enough that by 1980 the detailed plans for early ventures in space manufacturing and construction were well along; indeed, some preliminary experiments had been performed during the earlier space flights of the '70s.

Even after the first successful Shuttle-based experiments aboard Spacelab were reported by the news media in 1984, it took several years for the public to adjust to the approaching reality--that space could become industrialized relatively rapidly. Perhaps the completion and operation of the first space station in 1992, continuously occupied by astronauts, followed by the construction in space of a 100-meter-diameter antenna in 1994--both highly publicized and well-photographed events--were among the more significant experiences which affected the public's MISS imagery. Through television many people were able to become "sidewalk superintendents" of these milestone events and were thereby better able to bridge a gap which otherwise would have required a quantum jump in imagination.

The early prototype MISS products soon became highly valued collectors' items. The first crystals, plastic spheres, biologicals alloys, whiskers, silicon chips, glasses, castings, and ball bearings from the space laboratories indeed became prized museum pieces. But more important was the spreading knowledge of the special properties and commercial use of MISS products and processes--and of the potential for constructing large space structures of many kinds.

Having witnessed the construction of the first relatively simple installations in the form of modular depots, habitats, R&D laboratories, antennas, etc., the elaboration of the more complex space stations to come could be depicted and accepted more readily. Thus, psychologically the stage was set for a flurry of new interest in the development of Space Industrialization (SI). Shortly afterwards, in the late-'80s, when it became understood that excellent profits might also result from many of these ventures and that the potential for future growth was very large (some claimed, "unlimited"), the fancy of many investors was ensnared and the first boom in Space Industry stocks was on. Of course, some were foolish enough to make naive investments. Also in those days some unscrupulous commercial promoters existed who preyed upon emotional outbursts of this type. But the few cases of incompetence or fraud did not seriously detract from the excitement of the impending developments. The first major commercial SI facility was completed

Table 11
ORBITAL TRANSFER VEHICLES IN OPERATION OR IN
DEVELOPMENT BEFORE 2000

<u>PROPULSION CONCEPT*</u>	<u>YEAR DEMONSTRATED</u>
1. IUS AND SSUS (SOLID PROPELLANT)	1980
2. LARGE SOLAR SAIL	1989
3. CHEMICAL (F ₂ -N ₂ H ₄)	1989
4. LARGE ION ENGINE (Hg)	1991
5. CHEMICAL (F ₂ -H ₂)	1992
6. COLLOID THRUSTERS	1993
7. E-M ACCELERATOR (MPD)	1994
8. BEAMED ENERGY	1995
9. NUCLEAR FISSION ENGINE, 1ST SPACE TEST	1997
10. ADVANCED METASTABLE CHEMICALS	1998
11. OPERABLE LARGE NUCLEAR FISSION ENGINE	1999

* IUS: INTERIM UPPER STAGE
 SSUS: SPINNING SOLID UPPER STAGE
 E-M: ELECTRO-MAGNETIC
 MPD: MAGNETOPLASMODYNAMIC
 CHEMICAL SYMBOLS--Hg: MERCURY
 F: FLUORINE
 N: NITROGEN
 H: HYDROGEN

In 1994. It was nearly completely automated, yet about 12 people had to live in space just to operate and maintain the facility. Its first commercial products were biological materials of great purity unavailable from earth-bound processes (vaccines, hormones, enzymes) and processed silicon "chips" for computers. This facility was followed only six years later by one more than 5 times as large, operated by about 25 people. Soon after that production in space as a concept was to become routinely accepted. Even a "steel mill" in space was believed to be only a matter of time--at least it could no longer be a startling surprise. Space technologists of the time, of course, were thinking more about high-technology processes involving computers, lasers, robots, space vehicles, lunar observatories, expeditions to Mars and space colonization.

F. Lunar Program

By the mid '90s the Moon had been mapped by automated orbiting vehicles of both the U.S. & U.S.S.R. Also there were enough space tugs available by then to establish and supply a manned lunar base. The first arrivals (from a joint U.S., Europe, Japan and U.S.S.R. project begun in 1994) landed on the moon in 2004 to set up a temporary station for scientific and exploratory purposes. Subsequently two permanent colonies were set up, one on the far side of the moon to permit optimum astronomical observations, the other on the near side for a research laboratory and exploration center. By 2008 facilities existed which allowed twelve people to stay "permanently" on the moon. Supplies had been delivered regularly to help construct their underground habitats and develop various surface operations. These first colonists (9 men, 3 women) were an extremely capable group which, within a year, had found water sources on the moon that in some places could be tapped by wells less than 200 feet deep. This discovery made it certain that the moon would soon become a much more important link in future space programs.

In principle, because of the availability of water, the moon could soon provide essentially all the material needs of its inhabitants and become a relatively inexpensive source of materials for space structures and of propulsion fluids for space vehicles. During the next quarter, the industrial program for developing lunar resources was to make possible the construction of the first large colony in space at the L-5 "point."

A major goal of the early lunar explorers was to establish the feasibility of using the moon for many purposes other than scientific observations. Although the anticipated scientific rewards related to astronomy, geology, and astrophysics alone were believed to be sufficient to make the venture worthwhile, a huge long-term payoff depended upon the successful solution to a number of problems such as (1) finding water; (2) establishing the feasibility of a "nearly" closed-cycle ecology; (3) demonstrating the feasibility of living comfortably for months or years at 1/6-G and returning to earth without deleterious health problems; (4) proving the feasibility of mineral exploration,

mining, and smelting; (5) successfully resolving the sociological problems which tend to arise in any new environment, but which could be especially severe when the change is as sudden and as encompassing as that posed by the airless "barren" moon where each lunar day is 14 times longer than an earth day.

If the satisfactory resolution of these technical and social problems could be achieved then the feasibility of colonizing not only the moon but the "whole solar system" might be established, in principle. That this feat was essentially accomplished on the moon by the year 2010, less than 60 years from the time the first small earth satellite was launched, provides a stunning perspective on the great technological and societal transition that began in the second half of the 20th century. (During most of that same 60 year period, paradoxically, many citizens, and even some national institutions, were actively encouraging, if not demanding, a return to a former and simpler way of life. They had been led to believe that insufficient energy and materials would be available at reasonable costs to support the traditional progress-oriented activities of human civilization for more than a few decades.)

G. Early Space Tourists

In 1993, when it was agreed that the Space Shuttle had been adequately tested, a prior plan was carried out to demonstrate the utility of this vehicle as a "spaceliner" by introducing the public to the concept of commercial space tours. This first tour was a very well publicized three-day voyage to low-earth orbit which included a rendezvous with the recently completed Space Station. The special passengers chosen for this voyage were NASA's director, the governor of Texas, 2 Senators, 6 Congressmen, the French ambassador and 12 other VIPs, (6 from Europe, 2 from Japan) together with Marlon Scott and Elizabeth Welsh, at the time the best-known movie actor and actress in the U.S.

The special two-hour videotape documentary of the event became a tremendously popular worldwide success--in large part because the enthusiasm emanating from the famous actors was vividly conveyed by their spontaneous enthusiasm during the voyage. In addition their subsequent "orchestrated" television appearances further stimulated public interest in space projects--especially space travel. This single event helped the average citizen realize that the potential of space ventures could be perceived as a long term set of growing activities with great commercial promise. Of course, the array of social services supplied by the space program, as they became more fully appreciated, also made it increasingly popular. This popularity stemmed mainly from the publicity surrounding weather satellites and advanced COMSATS. Gradually the public also came to appreciate other earth-application satellites as well as the scientific advances made possible by space probes and planetary exploration. For example, during the 1990s, Future Space Developments became a standard course taught in many colleges

and technical schools around the world. However, the realization by average citizens that perhaps they, too, or certainly their children, might soon be able to travel safely to outer space--perhaps even stroll on the moon--was crucially important in creating supportive public attitudes. Outer space, more and more, became an exciting frontier which anyone could experience indirectly; and for those with a sufficiently strong desire the dream of actually going up there had become a potential reality.

Indeed by the end of the century, after the SDLV became operational, a new company, International Space Tours, Inc., announced that 600 people would "tour outer space" that year in the first commercial system licensed for the purpose. The cost (in 1975 dollars) that year was to be \$.5 million for a 5-day tour confined to near-earth orbit. Still, the demand for seats was several times the capacity of the system--even at that price. It was a good start for a fledgling business, one that was destined to become one of the world's largest.

H. International Cooperation

The Apollo moon landings had largely been driven by a feeling in the United States of a need to recover its (Sputnik) shattered image as the world's leader in science and technology. The Americans assumed it was a race and devoted the resources required to win--even though the Soviet Union denied it was entering any contest. The enormous international prestige that the Americans gained from their successful program was frittered away afterwards as the national malaise of the '70s set in. The flood of socio-political problems during and after the Vietnam involvement turned the U.S. public away from "large" space budgets. The conventional wisdom of the gloomy '70s claimed that, instead of spending tens of billions of dollars for "a few moon rocks," the money should be directed towards social purposes. The one-sided space "race" had indeed ended. As its budget declined and its world-renowned capability eroded during the decade of the '70s, NASA wisely attempted to stretch its resources through promoting cooperation in space ventures with the rest of the developed world, including the U.S.S.R. The cooperation effort was publicly announced but was treated with suspicion by many Americans, who saw the Soviets as their major potential enemy. But within a few years cooperation among the Western nations became effective, and to some extent with the Soviets as well. Although its beginning was slow the interaction among the various national space agencies was to bloom into an enormously rewarding program for all humanity.

The major milestones of the 20th century cooperative efforts were the U.S.-S.U. Apollo-Soyuz linkup of 1975; the 1984 Shuttle launching of the Spacelab module built by the European Space Agency; the first space tour with VIP passengers from several countries, mentioned above; and, perhaps most significant, the international agreement in 1998 to begin the \$50-billion 10-year program to create the so-called Super Shuttle STS--the first fully reusable unmanned HLLV-SSTO 1/2-million-pound

vehicle for launching payloads to near-earth orbit, in addition to a new array of advanced "space tugs" to complement this launch capability. The program soon grew to a \$100 billion effort but this extension was a measure of its success, not the result of cost overruns. NASA had the central responsibility and added to its successful management history by keeping within the budget. The design of the second-generation SSTO vehicle that evolved after the end of the century incorporated the technology based on a new superfuel which helped make the improved performance feasible. This vehicle would triple the former SSTO's payload capability, with the same gross weight at lift off (about 10 million pounds).

The major benefits from the cooperative international effort included (1) avoidance of duplicate development through technological exchange, (2) earlier funding of huge projects, (3) the establishment of international laws and procedures for settling disputes about "rights" in space and on planetary bodies, and (4) perhaps most important, the effective restriction of the use of outer space to peaceful purposes (COMSATS and observation satellites for military intelligence were allowed, but all weapons in space were strictly forbidden).

International cooperation in space, which many skeptical analysts had predicted would soon decline or collapse for the usual political reasons, instead soon gave rise to an unexpected aura of the kind that is often associated with successful enterprises, and resulted in the rapid sharing of information, mutual technical assistance, and a minimum of friction among the personnel of the various nations. Indeed, in each participating country an attitude gradually spread among those associated with the space program that resisted political pressures seeking special national "advantages." Because those projects associated with the cooperative development of space were able to avoid most of the national struggles for political advantages or ideological goals, it is not surprising that the space community increasingly became international--and eventually, intrasolar--in its perspective.

I. The Emerging Space Culture

Within each nation the natural heroes among those interested in a long term movement into space were the astronauts. For them the work which they had to do literally became a full-time occupation--roughly a 100-hour week. Quite generally an astronaut's occupation also became his primary recreation. A self-selection process evolved that effectively weeded out any aspiring astronaut who was less than completely dedicated to space projects. Still, the competition became fierce and remained so for over 50 years. The astronaut profession became one of the most "glamorous" in technologically advanced societies. The successful competitors evolved into a new elite culture with a commitment to their profession that the media often described as a new kind of "religion"; one in which they were viewed as the "high priests"--yet no formal rituals or dogmas were practiced or needed.

Obviously the space culture was not planned, it just happened; and as it grew it gradually transcended its former boundaries or "bonds" of chauvinistic nationalism. That new attitude was not always understood by those outside the space community, even after it became a prominent theme in the communications media. The astronauts had found that direct physical experiences of transcending the surface of the earth helped create a psychological counterpoint which led them and the other members of that community into a commitment to a way of life, a spirit, which transcended earth-centered national traditions and cultures. That sociological development became one of the major factors which led to some phenomenal changes during the 21st century. More about that later.

J. Health Aspects of Manned Space Developments

As soon as the possibility of sending humans safely into earth orbits was considered to be feasible it was also recognized that one of the crucial factors, perhaps the most crucial for the long-term prospects of manned space ventures, would be related to the effects of prolonged space voyages upon the health of astronauts. In which ways would space travel and space-based occupations be found to be beneficial or hazardous to human health? How might the benefits be improved and the hazards reduced? Those questions had to be answered. If astronauts had to become a class of health-sacrificing "martyrs" then severe limits would be placed on the potential scope of space-based civilizations. Of course, it was known that much could be accomplished in a space program based only upon the transient use of astronauts, with each one making a minor health sacrifice. This could be accomplished by developing systems that were designed to minimize the use of human beings and restricting the time any of them would spend away from the protective environment on the earth. However, the prevailing attitudes among space-oriented planners considered such an approach as a fallback position of last resort.

The great task for the biochemists, physiologists, physicians, and other professionals in space-oriented life sciences was to make the experiences in the space environment, on balance, beneficial in terms of physical health, if at all possible. Numerous problems were to appear, many of which were only dimly perceived during the 20th century, let alone understood. The life science research programs which at first had been only modestly funded became impressive by the end of the century. Indeed they grew relatively more rapidly than most other portions of space budgets and by the year 2000 exceeded \$4 billion annually (worldwide).

By that time the major problems had been formulated and some potential solutions were in sight. Indeed, by then it was confidently predicted that through a carefully designed program the health benefits of space-based operations could exceed the health hazards. Thus it was conjectured that over the following 50 years it could be demonstrated

that living in space would become associated with significant net health benefits. In fact, the perceived turning point came in the year 2024. From then on the remarkable "exodus" into space which has occurred became inevitable in principle. Only the timing was necessarily somewhat uncertain, since additional technological developments, which were "soon" to appear, were required to give humans the ability to live almost anywhere in the solar system, and eventually even beyond it if they so desired--but more of that later.

The principal health problems that had to be solved initially were (1) the ones associated with prolonged weightlessness or near-weightlessness, (2) those associated with radiation, and (3) those associated with a closed cycle or very nearly closed cycle operation of a space station, colony or "spaceship." One of the marvels in the history of science is that not only were these problems eventually solved but that, as an unanticipated benefit, humans born in the space environment were to become physically and emotionally relatively healthier than those born on earth. Indeed their natural longevity is now expected to be about 30 years above average, and their mental capability, on average, appears to be significantly better as well. An improved human being, substantially improved, emerged from the combined efforts of space scientists exploiting the natural benefits obtainable from the relatively benign space environment--once routines were developed that permitted an optimized utilization of the range of artificial gravitation readily available to the "permanent" inhabitants of space.

K. Spinoffs

That research and development, on the average, may be a good societal investment, is an idea that has always been obvious to people who value progress available through technological advances and economic growth. For them the ongoing political or bureaucratic struggles related to R&D budgets are generally about how much to invest in which kinds of R&D. In this context, one of NASA's early problems arose because its very rapid early growth, which culminated in the sensational Apollo moon landings, led to budgets which became hard to justify to the "man-in-the-street" on an economic basis.* Having won the "race to the moon" at a cost of about \$40 billion, NASA's budgets declined steadily in the subsequent decade. During the 1970s it was not apparent to the U.S. electorate that the space effort should be sustained because it would be an economically profitable investment in R&D. More than a decade was required for the situation to change--that is, for the U.S. public to conclude that investments in space were a long term bargain, perhaps one of the best economic investments they could make at the federal level. Their persuasion came about gradually, in part due to the perceived

*A historical perspective on the attitudes of human cultures toward new frontiers is given in Appendix B. It suggests that economic considerations were usually dominant prior to the 21st century.

importance of past technological rewards, as the potential for future technological spinoffs became better understood. After all, the growing importance of COMSATS, integrated circuits, pacemakers, improved weather prediction, and some of the stunning prospecting successes credited to the LANDSATs (to mention only a few examples) alone justified the historical expenditures on space projects up to the late '80s. After that time U.S. budgets for space-oriented projects began to grow rapidly. As public attitudes changed NASA was no longer seen as an interesting but expensive "toy" but as the manager of one of the better investments in the future that required federal funding. The space program entered the 1990s with no major boondoggles to mar its history, while its successes were deemed not less than a catalogue of marvels by most of those who took the trouble to examine them carefully.

By the late '90s, moreover, many of the important spinoffs had had sufficient time to emerge from the complicated process of developing, testing and marketing. By then analysts had also developed sound methods for estimating their economic value. The results became widely accepted as a calculation of the minimum impact of the value of space investments, even though it portrayed envious record. In addition, the space program was given credit for its many important contributions to basic sciences, ones that could not be quantified but which were publicly extolled as priceless. During the later years of the 20th century the discoveries of extraterrestrial primitive forms of life, black holes in the galaxies, and unexpected pulsations in the sun, for example, led to several revisions in previously accepted scientific formulations of some basic laws of nature.

Paradoxically perhaps, but not unusual as a theme in man's history, the funding of U.S. space projects during the '70s was being eroded just as the results of prior efforts were beginning to shower increasing benefits on Americans, indeed on the world. In business language the space program was being "sold short" just before its true value was about to be recognized. All that is changed after the late '80s. By the end of that decade the popularly accepted "rule" was to emerge from the well-known Apex Institute study that the effective economic return from prior investments in space technology should yield at least the equivalent of 20 percent per annum for 20 years.

Changing perceptions and attitudes led to the phenomenal growth in space-oriented developments that began in the late '80s and has continued until the present time on a worldwide basis. Private investments grew more rapidly than public ones, but did not exceed them until the year 2045 because of delayed starts and much smaller initial investments, in addition to the inevitable political problems. Thus, technological spinoffs of the space program, almost a throwaway concept to NASA in the '70s--a straw to grasp in attempting to justify its existence and restrain budget trimmers--after 1990 were to furnish some of the leverage which reoriented the public's perception about the value of space activities.

L. Milestones

From a review of budgets or progress in space it is clear that the last quarter of the 20th century began somewhat slowly but finished with a roar that became an omen of the future. A perspective on this early period can be found in the data of Table 12. It was a time of growing excitement. Of course, even in the late '90s a few protesting voices could occasionally be heard predicting gloom and doom ahead--but they grew fainter with time. The extraordinary changes in technology coupled with the rapidly-expanding success-oriented space cultures which had sprung up in many countries merely ignored the gloomy forecasts. Institutions dedicated to the future of space proliferated during those times and attracted participants from all age groups, but especially from the youthful ones. The gloomsters asserted that it was just another passing fad--but their predictions were soon to be shattered.

Still progress during and after 1990 was constrained, not by funds but by availability of trained personnel and the inherent limits posed by the need for thorough planning and testing of each step in each new project. As a result the pace of space development was at a maximum consistent with safety and efficiency during the decade before and the decade after the year 2000.

Table 12

U.S. SPACE DEVELOPMENT MILESTONES (1976-2010)

	BUDGET		
	CONSTANT \$1975		
	WORLD	U.S.	
1976	9.0	3.4	Viking-I & II
1977	9.0	3.3	LANDSAT-C, HEAO-A, Voyagers-I & II
1979	9.1	3.2	SEASAT-A, NIMBUS-G, TIROS-N
1981	10	3.1	Shuttle tested in orbit, HEAO-C, MAGSAT, SMM-A
1984	12	2.9	SPACELAB-1 Symbolizes New Era of Cooperation
1986	13	4.0	1st LEO Space Station being engineered, Space Telescope launched
1988	16	5.0	1st large antenna (50 meters) in LEO, SPACELAB 4
1989	18	5.8	Improved Shuttle increases payload 20% automated Lunar Rover landed
1991	21	6.5	International Navigation System
1992	24	7.5	100-meter microwave antenna, U.S. Personal Communications System, Global Crop Prediction System. 1st International (U.S., Canada, Japan, ESA) Space Station--6 people.
1993	27	8.5	Saturn orbiter launched, Disease Vectors System operational
1994	32	10.0	Asteroid Rendezvous Spacecraft launched
1995	40	13.0	Global Air Pollution Analysis System launched. 1st Space-Industrial Facility (4 people)
1996	45	14.5	Large Reusable Chemical OTV.
1997	50	16	Expanded SI facility (20 people and 1-MW power). Beamed Energy OTV operational, Severe Storm Prediction System (A) \$50-Billion Program (International) for SSTO launch vehicle, Expanded LEO space station accommodates 22 people; experimental platform in GEO with 100-antenna
1998	60	20	Advanced Weather Prediction System, Expanded SI facility (20 people and 1-MW power).
1999	70	24	2-Kilometer diameter antenna constructed, Marine Resources System
2000	80	30	Multi-Service U.S. Communications System
2001	88	35	1/2-million lb. payload SSTO HLLV operational, Earthquake Prediction System launched
2002	98	39	2nd Space Industrial facility launched (10-MW SSPS and 50 people), Multi-Service Int'l Communications System
2003	109	43	Advanced Nuclear OTV Funded, Permanent LEO Modular Space Station for 50 people Completed. 800-meter GEO antenna
2004	120	47	1st test module for L-5 Station launched (6 astronauts), 1st Moon colony established (12 people).
2006	140	55	1-1/2 million lb. payload HLLV operational, 1st Fission-Powered OTV tested successfully.
2008	160	60	Lunar colony expanded to 30 people
2010	185	70	

OPTIMISTIC SCENARIO
PART II: FIRST QUARTER--21ST CENTURY

A. World Economic Growth: A 100-Year Perspective

During the 21st century the explosion of technology, the explosion of knowledge, and the consequent increase in the wealth of the world was, in the U.S. tricentennial year, 2076, to reach proportions which would not have been believed possible by 99.99 percent of the world's citizens a century earlier. Moreover, it is also now clear that this growth phase will almost certainly continue. In this tricentennial year, any perspective on mankind's destiny appears to be far different from those which were visualized and recorded a 100 years earlier--except perhaps for a few scattered projections by science-fiction writers and futurists that were not taken seriously when they were made. The changes that occurred between 1976 and 2076 have been enormous and pervasive, if somewhat uneven in their impact upon various existing cultures.

For example our economists now estimate that the gross world product per capita over that 100-year period--assuming that such quantitative comparisons are meaningful--rose to about \$30,000 in 1975 dollars. That number tells us that a family of four on average now receives an income which 100 years ago was associated only with "millionaires". Of course, the bulk of the world's population then was still associated with relatively underdeveloped countries. However, even the poorest countries today have reached the level of \$10,000 per capita, again in 1975 dollars--an astonishing improvement, in retrospect, from the subsistence levels of the 20th century. Moreover, it is clear that most of them will close the remaining gap rapidly.

For many of the underdeveloped nations analysts had made differing but generally somewhat gloomy "prognoses" during the late 20th century. However, as practical forms of assistance from institutions in the more advanced countries were created and made available, the experts came to realize that no more than two generations--roughly 50-75 years--would be needed before most of the former economic distinctions, and many of the undesirable social ones, would be relegated to history.

By the year 2020 a prevailing ethic emerged among the technologically advanced cultures that, in effect, encouraged each human being to become integrated into at least one of the groups which are now known as members of the Solar Civilization. This transformation was to be accomplished by each person as optimally as possible, in accordance with his or her heritage and innate talents and with as much help as could be given and accepted. However, the advanced societies were only encouraging, not demanding. Anyone who wished to do so could choose instead among other lifestyles which were variously labeled: hedonistic, artistic, bohemian, traditional, contented, or natural. Poverty or crime stemming from inherited emotional or mental defects or from the impoverished environments found within most cultures of previous centuries, was to

all but disappear by 2050; thus lifestyle choices could usually be made without duress. Also, by mid-century little resentment existed, or was expressed, between those who became attracted to the outward-bound culture and those who chose the more relaxed lifestyle of the earth-centered cultures. The more traditional cultures did continue to have to cope with a much higher level of crime as that tends to develop in relatively permissive societies which unwittingly encourage what in the 20th century was called the "weak superego" for want of a more scientific explanation. Consequently, cheating, vandalism, theft, and some irrational violence still occur--but much less than before, and it seldom spills over into any of the cultures which are members of the Solar Civilization.

B. The Computer--Once More

The electronic computer which had not only made rapid technological change possible, but inevitable as is now obvious to all, had by about 2025 reached its nearly ultimate capability in terms of intrinsic developments in hardware. That is, by then the various possible designs had approached near enough to the theoretical limits that these limits precluded more than another factor of 5 in computational speed, by another factor of 10 or so in memory density, or another factor of 10 in reliability. Indeed by that time reliability had increased to the point that the probability of failure caused by random external disturbances which might affect some component of a computer--disturbances such as penetrating cosmic rays or from relatively large meteorites in space applications, for example--usually determined the basic reliability of the system.

Also by 2025, in addition to near-optimum reliability, the figure of merit of commercial computers* was about a thousand million times greater than that in 1976. Nevertheless, this exceptional hardware did not imply the end of progress in computers' usefulness. Indeed, in a major sense it was just the beginning. Increasing accomplishments were still to arrive in an endless stream in software and in computer architecture--that is in the programming and networking of large arrays of computers--as well as in ingenious adaptations to automated processing, product design, robotics, and algorithms for problem solving--adaptations which some people had long ago termed "artificial" intelligence. Of course the distinction between artificial and human intelligence has become increasingly blurred over time as the human-computer interface became more and more intimate and intertwined.

The earlier fear, especially among the artistically inclined, that a computerized civilization would make humans become more "mechanical" is

* A practical figure of merit must be related to computer's purpose. Generally it will be based on a formula related to processing speed, memory capacity, access time, data transfer rates, weight, volume, reliability and cost.

now only an amusing recollection among the numerous myths in history. The sense of freedom, the quality of life, the expectation of excellent physical health including the elimination of all bacterial and nearly all viral diseases, the conquest of birth deformities and the ability to prevent or release individuals from mental "boxes" such as autism, schizophrenia, and severe neuroses; these all became available by the year 2025 because of the computer. As a result within the dominant knowledge-oriented cultures improvements in mental and emotional health helped create a better environment in which each individual's productivity could, in principle, if not always in actuality, be tremendously enhanced--especially as the physical resources and information needed to assist individual productivity were also constantly increasing.

C. Space Developments

1. Infancy to Adolescence

The second half of the 20th century is now generally regarded as the infancy of space development. During that time the utilization of space for science, exploration, communication, earth observation, and industry was shown to be possible and the first steps into space were taken as an earth-based infrastructure was being created to support the expanding program. It is logical to surmise that in those early years a series of technological marvels or "miracles" was occurring in the same general sense as it is currently. But then, for the first time ever, human beings were able to leave the earth on voyages into outer space after countless millennia of surface-bound existence amid strife-torn civilizations. This period of "space-infancy" was followed by the "adolescent" quarter, 2000-2025, during which the excitement of space expanded rapidly into a new generation of enthusiasts whose heroes from childhood had been the "captains" of the great spaceships (the successors to Saturn V and the Shuttle)--but captains derived from the reality of space exploration instead of fiction.

This quarter was to be one of accomplishment, investment, growth and hope that would reorient most of the cultures of the entire world, and that would offer them tangible evidence that any culture could understand that its future could be secure and its horizons essentially unlimited. As one small example, it was in this quarter that not only short-term weather prediction but longer term climate forecasting (up to several months) became sufficiently accurate that a profound sense of confidence in that service came to prevail throughout the world. "Knowing" the weather accurately for a few days or weeks was pleasant and, in a few specific cases, vital. But of truly great importance, especially for the developing nations, was the new capability to anticipate a drought or a period of unusually heavy precipitation months or more in advance.

Earth-applications satellites matured into huge commercial enterprises that furnished "indispensable" services. Unanticipated earthquakes became

memories. Precise navigation became cheap. Collisions of ships or aircraft virtually disappeared. No company explored for minerals without first utilizing processed data from space. No one any longer feared being lost in a remote mountain or jungle (all the wrist communicators and backup "emergency-beepers" in the group would first have to be lost or smashed--a million-to-one chance).

Long-distance communication, over 10,000 miles, came to cost about the same as short-distance communication of one mile. In either case the signals to and from CO? ATS traveled about 50,000 miles. But the service was cheap and used a lot--by video or audio as people wished. Holographic imaging was also readily available where accurate 3-D images were important enough to justify the higher cost.

What became particularly fascinating to many earth-bound observers were the large space structures and the automated machines that maintained and serviced them; viewing of those operations were available through video transmissions. The weird-looking array of teleoperators that replaced malfunctioning modules and the preprogrammed robots that serviced these modules and restored their functions could be observed in action and entertained surprisingly large audiences. The earlier (year 2000) estimates for the relative number of humans who would be required for maintenance of the large space-based based communication systems had been reduced by more than a factor of 10 by 2025--partly because of greater reliability, partly because of unanticipated advances in automated maintenance.

The huge space structures themselves added to the former wonders of the world. Many of them were miles long in at least one direction; some with symmetric geometries were the size of cities. However, they were gossamer thin when viewed at close quarters. On earth they would have been quickly destroyed by a light wind let alone any rain, hail, earthquake, or many other energetic phenomena associated with the earth's surface.

The array of functioning space vehicles were undergoing a long-term trend of improvement and diversity--in accordance with specialized applications--that was to steadily increase their operational efficiency. By 2025, for example, launch costs to LEO had dropped to one-third of those in the year 2000. This reduction coupled with increased per-capita income had made space travel and tourism a booming enterprise. While the need for human attendants for routine space maintenance and repairs had decreased, the demand for human "space guides," as those employed to facilitate the space travel industry were called, grew as fast as tourism itself. By the end of the quarter the first small space hotels, hospitals, and museums were functioning. Also, of course, the inevitable interplanetary races and other space sporting events (such as zero-G acrobatics and winged slaloms for "indoor" competition) were burgeoning.

2. Space Industrialization

The quarter also witnessed the initial great surge of space industrialization, the growth of which was to expand exponentially as the unique properties of space were coupled with advancing technology, decreasing transport costs and man's ingenuity to create a vast array of space products, processes and services. Eventually this was to lead to the construction in space of computer systems, laser communications, technological instruments, robots, cryogenic engines, space vehicles, beamed power systems, and habitats for large orbiting colonies, to name a few of the "products." The raw materials, of course, were to be increasingly obtained from lunar and asteroid sources--although the latter was just beginning to be significant by 2025. A major industrial emphasis of the period was being focused on better robots, the automated or "intelligent" machines which were to do the really difficult work without complaint or politicking and which, once developed and debugged, functioned extraordinarily well in the non-corrosive environment outside the earth's envelope.

This was the quarter in which private investment in space-based ventures began to compete with other glamour industries on earth--in countries (such as the U.S., Japan and Brazil) which encouraged private ventures to function in space. Although some institutions and individuals "struck it rich," that was to become less and less important within the Solar Civilization. It had become exceedingly clear that the principal benefits of space development and its spinoffs, as well as earth developments, would accrue to all of mankind and this fact, coupled with a steady reduction in economic insecurity almost everywhere on earth, led to a growing degree of international cooperation that would have shocked the traditional maneuvering politicians of the 20th century.

The first quarter of the 21st century was subsequently dubbed the Great Awakening. People almost everywhere in the world "awoke" to find that they no longer were destined to be poor; no longer needed to live with diseases or illiteracy; no longer had to be victimized by weather, earthquakes, or other forces of nature; no longer must remain isolated from other human cultures; no longer needed to live in fear of external invasions or of being sent into battle; and no longer had to risk becoming the unwanted dependents of others. The shackles on minds, emotions, and physical health were to be rapidly discarded--at least for the children. All but a few of the most remote and isolated cultures participated in this awakening, and even those remaining few were "soon" to join in.

In 2025 the world's investment in space ventures exceeded \$300 billion, a sum which if predicted seriously 50 years earlier might have caused guffaws or a call for a straitjacket. Yet the investments were constrained even at that time, not by bureaucrats haggling over budget allocations but rather by physical limits to the rate of expansion

that were demanded by careful engineering and sequential decision-making based upon tests and performance. It would not have been productive to have spent more. However, the expenditures on earth for health, education, and training of the new generation, although not directly oriented toward space, were to provide the basis for rapidly expanding space-oriented projects for a long time to come.

3. Colonization

The first serious design for one of the "large" L-5 colonies was started in this quarter (in the year 2020, to accommodate 2020 inhabitants). From its inception it was known to be an experiment whose failures or difficulties would provide the experience which could open the possibility of rapid future expansion. The stable L-5 region was clearly one of the preferred places for testing the concept that large space colonies might become one of the great developments of the Solar Civilization and provide a stepping stone toward the even more advanced concept of large colonies which could travel anywhere in solar space--perhaps even further, eventually. Naturally immense unforeseen problems hampered even the prototype project during both its construction and "debugging" phases. It was not until the year 2045 (25 years later) that all the important technical problems had been solved and a serious building program for L-5 colonies could begin.

The same kind of difficulties did not attend the lunar base program which expanded rapidly during this quarter. By 2025, 1,400 lunar colonists were engaged in an array of unique projects. The scientific ones emphasized astronomy, geology and closed-cycle agricultural research. The technological ones concentrated on exploration, mining, food production, surface transportation, and the now-famous electric launch facility which was first operated in 2023 and initially could "catapult" 2 tons of moon-processed material per hour into space for use at earth-orbiting space stations or at the L-4 and L-5 colonies.

Although planetary exploration by fully-automated probes and vehicles was a continually expanding program, manned exploration of the planetary bodies was to furnish its share of spectacular adventures as well as practical applications. By 2015 the first humans had orbited Mars and landed on its two small moons, Phobos and Deimos, to set up a fuel depot, a control system for roving vehicles on Mars and a small laboratory for observation and communication purposes.

By 2025, 200 astronauts were exploring some constant planetary bodies (with landings on the Asteroids, Mercury and Mars) and observing other from orbiting space stations where landings were not feasible (Venus, Jupiter, Jovian moons). These were courageous people risking life and health at the farthest frontiers in the spirit of true pioneers. The superb chronicle of their adventures is now taught to every child showing an interest in space exploration. In retrospect it appears astonishing that 95 percent of those explorers survived--although 15 percent of them had to be rescued at least once.

Each tragic loss was an occasion for grief and subsequent agonizing reappraisal. Each successful rescue, on the other hand, was followed by a public celebration and a burst of renewed confidence. Neither the astronauts nor the public had previously expected the survival rate among the explorers of distant planets to be as high as 90 percent. Consequently, despite the gloom surrounding each disastrous event, the remarkable survival rate and the drama of the successful rescues allowed the public to accept the risks involved.

D. Life Science in the Space Environment

I mentioned earlier that by the year 2000 a growing confidence had arisen among life scientists studying the health problems of space inhabitants. This confidence was bolstered by the relatively large budgets devoted to those purposes. Consequently it was no great surprise when, in the year 2025, NASA announced that it believed that the world's scientific community had "solved the critical problems" associated with prolonged missions in space. The solutions were complex in the sense that identical procedures would not apply to everyone who was to spend a year or more in space; rather there were, generally speaking, three major categories into which such travelers could be placed depending mostly upon age, natural variations in individual adaptability, and prior exposure to the space environment. For those naturally best suited to space, and who had begun their careers in a weightless environment before they reached 24 years of age, there were no limits to the amount of zero-G exposure--only a requirement for a minimum specified exercise regime and an appropriate diet. Those in the most sensitive category were generally past 40 years of age with the least acceptable natural adaptability; astronauts in this group would be required to spend at least 20 percent of their awake time in at least a 1/8-G environment--again with a suitable exercise and diet program. The intermediate category would need to spend 5-10 percent of their awake time at 1/10-G or more. Those in the latter two categories would obtain their minimum G-requirements in the artificial gravity of rotating space structures.

The above "solution" was a satisfying one because it was expected to result in a small health improvement at the 95-percent confidence level, and equivalent health (compared to an earth-bound existence) at the 99-percent confidence level. Thus the space experience for nearly every astronaut would offer somewhat better health as an added bonus. More importantly, the inference could be drawn that over time the relative health benefits derived from living in the space environment should continue to increase. Subsequently as these benefits were measured and found to be substantial they tended to encourage additional outward migration.

Exceptions to potential health improvement were involved in various professions: for example, it included those who participated in high risk space exploration or in space races. Those people generally accepted an unusually high exposure to radiation in pursuit of their careers,

in addition to a higher accident rate. Those were health and safety risks that could be calculated and kept within reasonable limits but which entailed irreversible costs. Another group included the rescue and maintenance astronauts who were called upon to perform emergency duties beyond the capability of robots. Again, in addition to the higher risk of accidents, radiation exposure beyond the limits set for more routine situations (space stations, lunar colonies) was the principal health hazard; separate standards of acceptable risk were set for these specialists.

Almost as important for the long-term future of space was the confirmation during that quarter of the feasibility of closed-cycle "agriculture" for large space stations or other sufficiently large orbiting colonies. This development made possible a program of extensive colonization at L-4 and L-5 and opened the way for long-term (greater than 5 years) exploratory missions to various planetary systems by a nearly unlimited number of people. Indeed it opened up the path to the eventual colonization of any habitable portion of solar space (which, volumetrically speaking, did not exclude very much) and any habitable planetary body.

E. Travel and Tourism

As much as any other index, the annual number of travelers to space provided a measure of the growing interest in and of the economic development of space. The number of tourists increased by about a factor of 200 during this quarter--reaching 100,000 annually--and was constrained by the capacity of available transportation, not by the number of willing travelers. The combination of increasing per-capita wealth, decreasing travel costs, and high standards of safety assured a continuing boom in this fledgling industry for the foreseeable future.

During the quarter the cost of a two-week tour including both geosynchronous and near-earth orbits fell almost 10 fold to \$250,000. Moreover, a limited number of higher priced tours became available, including a lunar journey for some of those who qualified and could afford the \$2 million fare. Still many qualified people who were willing and able to pay the fare could not obtain a seat. Preference was given to those who were active in space enterprises as well as priorities for their relatives--a policy which led to some grumbling among those who were disappointed. Also, to accommodate at least some of the younger and less affluent people eager for a space tour, a nonprofit lottery system was established in 2017 that enabled 500 lucky people to visit outer space that year. Lottery tickets, at \$100 each, became popular gifts. Currently that approach is still being used in some of the developing nations.

Many people found that they would rather enjoy space tours vicariously through comprehensive video programs, some of which used holography when

3-D effects were feasible and desirable. Indeed such programming contributed significantly to the education of young people interested in the space-oriented culture. But everyone knew that a truly deep aesthetic experience was only available out there in orbit, or on the moon.

F. Demilitarization

Growing international space programs had created some alarm in the latter part of the 20th century. Technological advances had produced a capability for very destructive weapons, defensive and offensive, as well as for commercial developments. Fears that almost any space installations could be quickly demolished by distant death rays might have created a serious impediment to space development. However, the demilitarization of space began to be effective after the celebrated "Solar System Treaty" between the NATO and Warsaw Pact countries was negotiated in 1998 and signed by all participants on December 31, 1999--a marvelous symbolic gesture with which the 21st century began. By the early 1990's former desires to extend military power into space had weakened. Partly it was because of the high cost but, more importantly, it reflected an emerging worldwide sentiment in favor of establishing a peaceful future in space for all nations, for all mankind.

The now-famous treaty is seen as a turning point, not only for space programs but also for the subsequent waning of the large national military establishments on earth. After 1987, confidence in successful solutions to the energy, mineral, environment and food problems perceived in the 1970s grew rapidly and helped lead to more stable and more prosperous economies. This outcome coupled effectively with the rising spirit of international cooperation in space efforts, and tended to reduce earlier incentives for promoting violent solutions to political problems. Thus, unexpectedly, 1998 came to be seen in retrospect as the turning point at which the militarization of the major national powers and their alliances began to shrink.

This change did not occur quickly; it began with a slow decline of military budgets and over time, almost imperceptibly, the earlier compelling logic for the maintenance of huge arsenals gradually disappeared. Nations did not reduce their military R&D establishments, and usually kept on building prototypes of new weapons and maintaining their intelligence organizations. But the overall strategic tone and military doctrine gradually changed to reflect the new perceptions of political realities. Any remaining interest in nations conquering other nations had all but vanished by 2015, at which date it was fully and overtly recognized and accepted as an obsolete notion. There remained, of course, a general understanding that the rise of "another Hitler" was not impossible in principle, and that continuing worldwide vigilance was needed for assurance that such megalomaniacs could not achieve control of any of the leading national powers. Even this fear, however, was to be essentially eliminated by 2025, partly as a result of the progress

in the life sciences which could assure the basic mental, emotional and physical soundness of all citizens through the prevention of serious genetic defects in the newly born, but mostly because of the spreading influence of the ideals of the Solar Civilization to whose members increasing individualism, democratic traditions, and a humanitarian concern for all less-fortunate people were all fundamental concerns. Thus, by the end of the first quarter of the 21st century the world had discovered that an era peace-on-earth (i.e., war avoidance) had evolved and had become part of the new style of life almost "by itself"--or so some claimed.

OPTIMISTIC SCENARIO
PART III: REFLECTIONS ON DEVELOPMENTS FROM 2025 TO 2076

A. Maturity in Space

The 20th century has been described as the infancy of space development and the first quarter of this century as its adolescence. It is now felt, to continue the analogy, that the world reached maturity in space during the last 50 years--however naive this statement may appear to be 50 or 100 years from now. After about 125 years of continued (some say amazing) growth many of us do feel a kind of maturity. Children today accept space travel as simply natural, much as children of the mid-20th century came to accept automobiles and aircraft.

During the early period of space development (i.e., in the 20th century after WW-II) space budgets in the developed nations were often thought of, strange as it now seems, as a kind of annual sacrifice; or sometimes as an entry fee to an exclusive "club"--composed of industrialized nations supplying funds to organizations like NASA which were devoted to the study of space science and technology through actual exploration. Ordinary citizens often had little inkling that there was much to be gained from this effort beyond COMSATS, a few extraterrestrial rocks and some astronomical observations which they had been told were important, though they had difficulty understanding why.

Today the rich rewards of those early efforts are apparent to everyone. The frontiers of space exploration have been pushed far beyond our most distant planet, Pluto, and the resources of space are being ingeniously utilized for the benefit of humans everywhere in the expanding Solar Civilization. Space budgets are now only called investments, and they have had a long record of economic success. This year, with \$10 trillion from earth sources and \$15 trillion of income from space production being reinvested, the total of \$25 trillion (in 1975 dollars) for investments is roughly 5 times the gross world product of a century ago. During that Bicentennial year the U.S. Congress was debating whether the (reduced) budget for NASA should be \$3.3 or \$3.6 billion. This year space investments from the U.S. will exceed \$5,000 billion.

B. Social and Economic Progress

By any historical standard prior to this century, the world has become relatively very wealthy in a very short time. Poverty, crime, and disease no longer have the meanings which existed "way back then"--during 1976-1986, the years for celebrating the Bicentennial, for example. Poor people today are so labeled because they choose to be poor; that is to live in the "style of their forefathers" without the benefit of hundreds of robots, without specialized knowledge, without most of today's technology and, naturally, refusing space travel. Of

course they are well off in terms of food, housing, surface travel and health care; and most of them are involved in their own choices of arts and crafts, sports and recreation. Generally these groups are held together by their religious convictions although a few claim to be almost purely hedonistic. Yet they have been a steadily diminishing portion of the world's population and now constitute less than 20 percent of the total.

World population is now 9.4 billion people and is expected to remain stable. Our extraterrestrial population, now at 40 million, is small compared to the total but it is expected to grow rapidly for at least several decades. As our world product is about \$290 trillion (260 on earth, 30 in space) the GWP per capita is almost \$30,000. Moreover, except for those who are poor by choice, the income gap has shrunk considerably from that of a century ago. Today the prospering South Asians and Chinese have attained a per-capita income level which is about 40% of the world average. This lag in relative income is mostly due to the fact that many of their older citizens did not have an opportunity for a thorough education during their school years--a situation that does not exist today.

Every child born after 2050 has been free from mental or physical defects (again excepting some among those who choose a traditional existence). Currently these children are being raised under ideal circumstances, as they can best be defined. Thus, by 20th century standards each child today is expected to develop into an intellectual genius, to be in nearly perfect physical health, to be emotionally alert and responsive without neurotic instabilities, and to live about 120 years with 80 of them being highly productive. Consequently, nearly every child born after this year is likely to be active during the celebration of the U.S. Quadricentennial, the nature of which I will speculate about later on.

C. Automation

The first 200 years of U.S. history coincided roughly with the industrial revolution. Thus, since the American revolution people in the more rapidly advancing technological cultures have devoted increasing efforts to developing, maintaining, and operating machines. During the last century this has not changed, but its qualitative and quantitative nature are obviously quite different. Of course, the world today might be puzzling to almost any visitor from the Bicentennial year. For one thing there are no observable pollutants from industrial enterprises. Indeed, most of us now live with very few of the background noises of the former civilization--the occasional exceptions are transitory experiences. Nearly everything called work 100 years ago is now being done by highly automated and usually "very intelligent" machines. Wherever the local environment is unsuited for human comfort our interaction with these machines, or robots if you will, is communicated electronically or optically from an appropriate distance. Maintenance procedures

are usually automated and specialized maintenance robots are designed to function reliably, especially in the more challenging environments, such as in the deep sea or on the lunar surface.

Most human beings today specialize in providing knowledge and skills which computers or robots do not yet have. Each person's many different "personal robots" have been programmed to assist him in his work; in addition everyone has at least limited access to the latest technologies such as space vehicles or computer networks. Scientists and technologists generally have access to whatever instruments or computational facilities they require--although where expenditures are required beyond those authorized by routine standards, peer-group permission must be obtained.

D. Computers and Electronics

A few more remarks about computers are in order before we get back to space. It would be almost impossible to describe to a person from the 20th century what changes the computer-based technologies have wrought. Perfect human health--mental, physical, and emotional--is a "computer product." That is, like most of present technology, it became possible only because of progress in computers. Present computer systems are optimally designed hardware components netted together in a worldwide electronic and optical network which simultaneously is both private and intimately public, as befits a good system. Thus any information anywhere about any subject that has been connected to the public grid is quickly available to anyone through electronic-optical information transfer--as is access to any person anywhere in the solar system, when such access is mutually desired.

Even today, though overall "efficiency," or capability, of our computer-based information network is estimated to be much more than a million times greater than it was at the turn of the century, our experts believe that there will continue to be remarkable improvements during the next 100 years--or for as long as people desire it, some believe. It would probably have been very difficult for even an informed citizen in 1976 to anticipate that after a mere 100 years the computer power available to each individual would exceed the total computer power of the world in which he lived!

E. Extraterrestrial

The expectation today is that the population in space will continue to expand for some time. On the moon today there are about 200,000 people, perhaps half of whom spend more time there than on earth and who have come to prefer it, partly because of the exhilarating low-gravity environment. Some people are predicting that the lunar population may eventually exceed a billion. Certainly we are aware of no major obstacles to this occurrence other than the debate about the lunar atmosphere. With a billion residents, the amount of gas leaking from

their "closed environments" and from automated lunar industry may become so great that the moon may acquire a sensible atmosphere--a potential annoyance to lunar astronomers as well as to the manufacturing processes requiring high vacuum. Most of our scientists believe that there are so many alternatives to the lunar platform for observatories that it would be better to "move some of the astronomers" than to restrict other lunar developments. It is also possible that the gaseous leakage can be adequately contained.

Because lunar materials are experiencing an increasing demand for use at space stations and orbiting colonies the mining activity is apt to grow rapidly for a few decades, or perhaps much more. The L-4 and L-5 regions have a population that nearly equals that on the moon and are the most rapidly growing space habitats and industrial facilities in orbit. Within the next few decades most of the newer space vehicles (except the larger SSTOs) are likely to be produced at the L-colonies. These two regions are evidently destined to become great industrial parks in the extraterrestrial Solar Civilization--at least that is the way it appears now.

Meanwhile the space frontiers are being expanded by exploration teams. Mars has about 2,500 people in its colonies now. Its low gravity pleases the surface residents, the more enthusiastic of whom predict that Mars will "soon" be engineered to provide climatic conditions on its surface suitable for the introduction of several kinds of earth flora and fauna. Today it is mainly a self-sufficient scientific outpost, but it also produces a substantial quantity of fuel for space vehicles which can be recharged from Martian orbital space stations.

The rest of the 20,000 exploring astronauts are well scattered over the solar system. Each planetary body is to be exhaustively investigated--by robots alone only where the environment is too hostile for human presence. All of the large asteroids will have been examined and catalogued before 2090. Some of them will be towed in during this coming quarter to provide exhibits, fuels and minerals for the planned Asteroid Industrial Park. Chunks of the more valuable asteroids, of course, are even now being moved regularly to the L-colonies; this freight has increased about 100-fold since 2050--last year about 10 million tons were brought into cis-lunar space.

F. Space Vehicle Developments

The most impressive achievement in propulsion, announced formally in 2072, just 4 years ago, was the new non-radioactive fusion-electric engine which operates at an efficiency of 80 percent and is expected to reach 90 percent during the next 10-20 years--that is, in the current model at least 80 percent of the fusion energy is available as electric energy for propulsion. In an alternate design the fusion products may be directly ejected from the engine without electrical conversion.

With this engine very large space vehicles should be able to travel economically at great speeds. Its capability will be particularly important for missions beyond the asteroids. Consequently, not only should the manned exploration of the distant planets and their satellites be greatly increased because of the power and efficiency now available, but the rate of expansion of the Solar Civilization into the farther reaches of the Solar System probably will double or triple.

Perhaps even more exciting is the potential, which now appears to be quite likely, that during the next few decades even more advanced fusion engines may open up the possibility of manned interstellar exploration--a persistent dream among the more devoted buffs of the Interstellar Exploration Society--one that some of them claim will become a reality within 50 years! Most of our scientists are dubious about that claim.

Although by using a kind of rough averaging we estimate that the cost of space transport has fallen during the last 50 years to about 1/5 of the cost in the year 2025 (it is now about \$8 per pound, in 1975 dollars, for a launch to LEO of a vehicle transporting people), there exists such a large array of special-purpose vehicles that statistical averaging obscures some of the important economies which are achieved by specific designs. Also, depending upon specific circumstances, the transport of human beings between orbits costs from 2 to 20 times more than that for most inanimate materials.

Transport time is sometimes an urgent consideration and other times not. For example, in transporting lunar raw materials or chunks of asteroids, the rate of arrival at the space industrial center is usually the dominant factor; whether the travel time is a week or a year is much less important--especially as robot-time usually costs much less than human time in the relevant systems. This is the reverse of the 20th-century relation in which automated machines or central computers generally cost much more than human labor on a per-hour basis. The income of a competent engineer is now about 10 times more than that of his counterpart a century ago, while the value of "equivalent" 20th-century automated machines, instruments, robots or computers has fallen by a factor of 10 to 100--if indeed the use of the term "equivalent" in this context has much useful meaning today.

G. Travel and Tourism

Because of the steady drop in costs the phenomenal growth in the use of space has set a new record, reaching 120 million travelers last year. The average length of time per journey is now over 30 days and the average cost for a trip which includes 10 days on the moon is about \$100,000. Space travel and tourism currently is a \$10-trillion annual business worldwide--about twice the entire world's GWP a century ago, and perhaps 30 percent of present annual expenditures in space development projects. A "standard" tour might spend several days in various earth-

orbiting space stations and industrial complexes, a week at one of the L-colonies, about 10 days on the moon and a few days visiting space museums, sports stadiums, and hospitals. Some of the features which have proved to be especially attractive are power stations, exploration vehicles, space robot displays, giant laser-communication centers, and astronomical observatories. However, many people have found that their greatest single spiritual experience came from spending several hours, or as much as a day, in a space suit, orbiting all alone. The first such experience is generally reported to be the one which is the most profound.

H. Interstellar Exploration

Some interstellar exploration buffs keep redesigning the space vehicles which they believe may soon be sent to investigate one of the nearer stars with a human crew. The estimate (in 2060) was about \$8 trillion for a vehicle with 20 people which might, with luck, make a round trip safely in about 150 years. While that is still too expensive the buffs claim that within 50 years the first such mission will be undertaken, perhaps even with a larger initial group--as none of the starters may be among the finishers. None of the problems involved in such a mission seem insurmountable, only costly, dangerous, and of questionable value. But when the total cost of such an adventure comes down to less than 2 percent of the GSP, who knows, the first star-bound explorers may prevail.

One-way scientific missions with robot explorers are now being launched regularly toward interesting stars, black holes, and various anomalous regions within a 100-light-year radius. Scientists are eagerly awaiting the returns from the first contacts which will occur in about 5 years, although it will take another 4 to 10 years to get the information back through the interstellar communication network, which the robots are installing as the vehicles reach out toward their destinations.

Black holes, as we know, are still tantalizing the astrophysicists. Several thousand have now been positively identified and the theory of their formation, sizes, and distribution is now well understood. Still the physical laws applicable to the processes within these holes have resisted the most ingenious attempts to understand them. For this reason the data that might be returned by the first probes approaching a black hole are eagerly awaited and, some believe, might revolutionize some of the basic theories of physics soon after they are received. Who knows what that might lead to?

Powerful astronomical instruments have mapped our galaxy in considerable detail. Of the planets as large as or larger than the earth that exist within 5000 light years of us, probably 90 percent have been identified and catalogued. At least 10 percent of them appear to have a potential for some form of life and perhaps 12 planets are considered to offer conditions that make advanced life forms possible. Only one of these,

however, is near enough to be reached by any of our probes within the next 50 years. Still the sensitive receivers of the interstellar communication system will be constantly listening from now on--and the system will be continually expanded into deep space and in many directions.

1. Solar Civilization Government

Even though certain residual traces of 20th century styles of government are still present, the concept of total sovereignty upon which the former nation-state system was based has largely been supplanted by our Solar Civilization and the institutions of various local cultures. With the elimination of poverty, crime, disease, insecurity, and war during this century and with the expansion into both the space frontier and the earth's oceans (6 percent of the earth's population now lives on floating cities) many of the traditional functions of nations were no longer useful. To what nation children born in space or in ocean cities should "belong" was a concept that simply eroded away. Language barriers were quickly transcended early in this century with computerized translators and over time the "natural" language of our present civilization became the common central one. Of course, many people are still facile in the languages with which they were raised and some of the remaining "poor" people speak only their traditional languages by choice.

But our present "government" would be incomprehensible to our great-grandparents of 1976. In those days politicians of democratic countries pretended to be the "servants" of the people, when in fact they held the power of masters and frequently used it viciously or stupidly, often covering up their deeper motives so carefully that they deceived themselves more than others. None of that is possible today. Dishonesty is no longer needed or useful; it is hard to find and parents are careful to exorcise it from their children when it appears. Governing today is serving the people and is not one of the more exalted professions. Effectively power exists in real knowledge and in specialized physical skills; no longer in hypnotic propaganda, wealth, or class traditions. Our society has learned in detail about the astonishing foolishness and irrationality which was inherent in people's behavior prior to this century, and which has fortunately become only a memory--a set of recorded events, unlikely ever to be repeated. Today, it is difficult for young adults to believe that they have only so recently, and luckily, emerged from the long era of "jungle" civilization.

The central goal of the Solar Civilization is to make life a glorious 120-year adventure for each citizen. Death, when it comes, is usually considered to be no more of a tragedy than a long sleep would be--except for chance fatal accidents, and these are relatively rare. Our fellow human beings, whatever their origins or destinations, are almost always a pleasure to meet and to interact with. That is our custom, and that is how people believe it should be--always.

OPTIMISTIC SCENARIO
PART IV: FORECAST: THE NEXT 100 YEARS

A. Future Exploration

Now what of the future? There have always been those who believed that mankind has progressed about as far as it could--but those opinions are not too numerous now and usually emanate from the traditional cultures. For most of our space professionals the gist of the future potential of space exploration is summed up by the phrase, the universe beckons. This phrase goes beyond the mere human visitation to other stars or their planets--an accomplishment not yet achieved but believed quite generally to be one which will become routine and whose beginning is even now on the drawing boards. More about such ventures later. First I simply want to set forth more fully the meaning of that phrase to the current generation.

It is taken for granted that the outward development of the Solar Civilization will continue in many of the directions now clearly indicated. All accessible planetary bodies will be mapped, explored and colonized--by humans where this is feasible, and by robots where (or while) the environment prohibits human access. Massive planetary engineering will be a constant program for each planetary body, whether it is a small moon or great Jupiter, itself. But there is no great hurry as such undertakings at present are interesting as scientific investigations, not as economic or social requirements. Even in their early stages such projects (assuming that the expected sustained technological advances in the efficiency of space travel do occur) should make the trip from earth to Jupiter, and soon the more distant planets, a frequent "routine" journey--less arduous by far than the trip from England to the U.S. during colonial times.

Travel in the solar system is now potentially available for almost anyone who has a strong desire or need for it, and living in a space colony is a commonplace experience for at least a million people; we expect that the space-based population could well expand to billions over the next hundred years. Wherever large groups of space explorers might choose to travel they can now take with them complete closed-cycle systems for relatively comfortable living, including the requisite, portable industries with a full set of operation and maintenance robots. Any vital information would be stored or made available through the laser-linked Solar Communication System. Thus the only significant communication or information delays among our Solar Civilization communities

*But who maintains the maintenance robots? Perhaps we might soon have super-maintenance robots to do that job. But then who maintains them? Historically thinking, it is we humans who must do the final maintenance. Consequently, that will be the limiting factor--or will it? Either way, it is going to be an exciting adventure!

will be the inevitable ones caused by the time it takes light to travel the intervening distances.

Perhaps (and this is my personal view) the shape of the future expansion of our Solar Civilization into space will be somewhat analogous to a slow motion unfolding of a gigantic explosion which over the millenia ahead would gradually reach outward to the limits of the universe in every direction. Thus, some people today visualize that self-contained, self-sufficient communities (with populations ranging from thousands to several tens of thousands, and for each person hundreds if not thousands of specialized robots) will gradually expand, first throughout the far reaches of the solar system, and then well beyond that--maintaining continual communications (indeed, becoming part of a grand communication network) but generally roaming farther and farther from the solar center.

The enormous energies available near the sun will not be available to those who are outward bound. But even now some of the energy needed can be plucked from the outer planets, soon from any passing comets and other space "debris," and finally even from the diffuse hydrogen atoms if not from the "vacuum" of "empty" space, if need be. Of course, fusion energy coupled with efficient recycling of matter inside each colony could if need be, provide the bulk if not the total requirements for almost any journey--even one to distant stars--that is now contemplated.

In this concept of our ever-expanding space-based civilization the design of complete systems for interstellar voyages appears likely to be substantially different from those generally visualized prior to this century. These concepts, usually involving speeds approaching that of light and possible round trips within a lifetime, are now deemed appropriate only for vehicles operate purely by robots--many of which are already proceeding at optimum speeds to the nearer stars. But voyages of colonies of people will take much longer and are likely to be part of the general long-term expansion into the galaxy, while maintaining intimate communications with all neighboring communities (those within a few light weeks or so). Thus the applicable image for the next few centuries possibly, is one of armadas of large self-sufficient space colonies emanating "radially" outward from the Solar System, maintaining constant contact through laser communications, drawing in increasing portion of their energy requirements (over time) from the endless resources of space and continually developing the community organization (and each of the individuals within it) while the grand voyage proceeds. The first destination of any first journey, which itself clearly must be a part of an endless process, can only be the first objective of the expedition. That journey would simply represent the physical segment in space-time that the community will be occupying as it proceeds with its business of living, learning, and interacting with the other communities of the expanding Solar Civilization.

The above image, of course, may change greatly during the next hundred years. To me it is simply the current most likely one. However,

since the part of this grand expansion that would leave the solar system with people has not yet begun--nor is it likely to for another 50 years or so at the earliest--who can say with confidence that it will come about as described? After all, there are still some who contend that even the "ultimate" constraint posed by the speed of light may yet be overcome when we have delved sufficiently far into the endless store of scientific secrets that nature only gradually reveals to us, a bit at a time. Obviously that alone could, and a few believe will, usher in an incomprehensible new universe of discoveries that would make the above image of the future appear to be naive--or primitive.

An awesome aspect of looking backward in time lies in the implications of the exponential nature of the knowledge explosion that has occurred over the last few hundred years. If that expansion is projected forward another hundred years at its recent growth rate it would imply, despite our impressive progress in space exploration, our current knowledge of the cosmos, and our understanding of the infinitesimal structures of the component parts of matter-energy, that currently we are still mere infants in knowledge--that the really impressive breakthroughs in comprehending the nature of the universe are yet to come. Each of the last several centuries has witnessed ever more awesome and radical changes than the one before, at least by one or more orders of magnitude where numerical measurements are relevant. Futurologists are very excited by the prospects ahead yet they must feel a little shaky inside at what might occur, knowing that beyond a few decades the future is essentially opaque, however much they may try to peer through it for a glimpse of what is to come.

In a more practical vein some long term projections for the next century, for whatever such exercises are worth (relatively little, judging from past experience), have been made by a team of futurists and I will mention a few of them now, more in the spirit of entertainment than as a serious guide to what will be.

B. 100-Year Projections

1) First, the population living in space should increase dramatically, perhaps to as much as a billion people by 2176. A significant fraction, perhaps even 1.0 percent, of them may be outward bound in the sense discussed above. Even the 1 billion total is an extrapolation based on a gradually diminishing "exponential" growth of the space-based population (see Table 13) and is coupled with assessments of the rate of future economic growth on a relatively conservative basis. The space population by then would be about as large as the population on earth--which is expected to remain at about the same level as it is today.

2) Space travel and tourism will grow rapidly but its nature will have changed dramatically by the Year 2176. Also the number of people traveling annually from earth to various space destinations

will increase by about a factor of 1,000. Even now space tourist is a term which is rapidly losing much of its former meaning. Except for first-time visitors most space travel is now associated with specific projects that the travelers are involved with. Whether a large space-liner or personal space vehicle is utilized for the journey will be a matter of optimizing the choice. A century or more ago a tourist was defined as a person traveling in a foreign land interacting with an unfamiliar culture, usually from a somewhat protected and insulated vantage point (or path). Today cultural insulation is largely non-existent--except among the remnants of traditional cultures that remain so by choice. Our knowledge-oriented civilization has no interest in developing tourism as a method of intercultural communication. Indeed, it would be an extremely inefficient approach. Information about any aspect of space cultures, as with earth cultures, generally is available quickly and accurately through the Solar Communication Network in any of the desired standard forms (i.e., visual, audio, holographic, symbolic, etc.) or any combination of these.

3) Economic expansion in space is projected to increase roughly by a factor between 100 and 1,000 (the median GSP projection for 2176 is \$12 quadrillion, for those who find such estimates meaningful) compared to a factor of 25 projected for economic growth on earth. The projection assumes the continuation of the relatively unproductive traditionalists, that relatively crowded conditions on earth cause investments to flow into space projects, and that because the climate and the diurnal cycle on earth are constraints on development, better opportunities and adequate resources will exist beyond the earth's atmosphere.

Within the world's knowledge-oriented cultures the average gross income of a family of four now exceeds \$120,000 annually and has been increasing monotonically (and almost exponentially)--(see Table 13). Although our total population (earth and space) is not expected to increase much during the next century, average income in terms of per-capita gross product should by then increase substantially, perhaps about 40-fold.

4) Space travel is soon expected to become much cheaper as the result of several imminent developments. One is the recoverable momentum system which will, in principle, enable exo-atmospheric travel to be almost free in terms of the amount of required matter (ejection mass) and energy, at least wherever travel time is not a major consideration and even that may be only a temporary constraint. For long journeys in which time is important, we have expectations of constantly-improving fusion engines. The futurists now anticipate that during the next 100 years costs will drop to about \$2 per pound (in bicentennial dollars) for transporting people from the earth's surface to near-earth orbit (freight should be cheaper, of course). However the more important aspect of commercial travel beyond cislunar space is the time/cost

Table 13

OPTIMISTIC SCENARIO
POPULATION AND GROSS PRODUCT
(PAST & PROJECTED)

<u>YEAR</u>	<u>POPULATION (BILLIONS)</u>		<u>GROSS PRODUCT* (\$ TRILLIONS)</u>			
	<u>EARTH</u>	<u>SPACE</u>	<u>EARTH</u>		<u>SPACE</u>	
1975	4.0	---	6.6			
2000	6.0	.4**	20	(.045)	.02	
2025	7.7	20**	50	(.037)	.36	(.12)
2050	8.8	500**	115	(.034)	4.0	(.10)
2075	9.4	1,000**	260	(.033)	30	(.084)

2100	9.7	.01	720	(.041)	180	(.074)
2125	9.9	.07	1,670	(.034)	900	(.066)
2150	9.9	.30	3,500	(.030)	3,600	(.057)
2175	10.0	1.00	6,700	(.026)	12,000	(.049)

* FIGURES IN PARENTHESES ARE AVERAGE ANNUAL GROWTH RATES FOR THE PRECEDING QUARTER.

** THOUSANDS

ratio. It is in this regard that the improved engines will be most useful. For example, it will soon require no more than 4 weeks for travelers to reach Jupiter without great expense or discomfort during the journey (i.e., at approximately 1-g most of the time) and only about 2 weeks in the event of very urgent business, although the latter requirement is not expected to be frequent--at least not during the next decade or so.

5) Our futurists expect that some of the most exciting possibilities that lie ahead will be related to the interaction of people and computers. As in the past we cannot see, except in vague--perhaps meaningless--ways, what the important discoveries or applications are likely to be. However, informed specialists continue to speculate upon potential "direct" linkages between advanced computer systems and the human brain. In principle that could improve human memory, greatly speed up thinking processes, and perhaps enable us to learn while sleeping (or even while awake--on an unconscious level). Technology already has led to considerable progress in all but the last process, but not by a direct linkage--rather through much better understanding of the electro-chemistry of brain functions. Even now, however, the innate capability of the healthy brain is known to be at least 100-fold greater in terms of memory than that which is usually achieved by our best students. However for creative problem-solving ability our scientists still can't make meaningful quantitative estimates of the human potential; it is only believed to be very much greater than that which we have experienced.

Coupling these possibilities with the evolving information networks and a growing number of trained contributors clearly makes the future continue to appear "explosive" in terms of its potential for new knowledge, just as it has been since the middle of the 20th century when the electronic computer appeared. More or less consonant with experiences of a hundred years earlier, our information systems still produce much more data than can be rapidly digested--an inevitable "problem" associated with rapid growth in the system's capacity. But, in retrospect, the progress is astonishing. About 200 million people are now professionally engaged in improving information and communication systems; all of them, of course also use the Integrated Information and Computing Network (IICN) as a tool to help with their specific tasks.

C. A Universal Brain?

One of the more common spectacular images of the future potential is that of a great "universal brain" composed of all of the brains of the inhabitants of the Solar Civilization linked optimally into the vast IICN which by innate design is self-programming and therefore is rapidly self-improving over time--even as it enhances the effective brainpower of its users!

Although individuals still conceive of themselves as independent autonomies--as they always have done in the past--currently they are

more aware than ever of their interdependence through the IICN. The major difference between current attitudes and those which prevailed a century or so ago is that this interdependence is now considered desirable; that rather than promoting robot-like humans it creates "human-like" robots where these are desirable, and frees human beings to perform ever more creatively in endeavors of their choice. No adult is ever forced to participate in any project, and anyone who so wishes can leave the knowledge-oriented culture without fear of reprisal. It even happens occasionally, although quite rarely. Actually, the drop-in rate in recent years has been 100 times greater than the drop-out.

Thus, the expectation exists that in whatever manner the "Universal Brain" evolves into a more meaningful entity it will be an entirely desirable and natural evolution that will almost continuously be recasting the image of the human role and its destiny in the universe. Few people now doubt that over the long term (more than 100 years from now) that the concept of human destiny will come to include the exploration of the whole galaxy through actual visitation and then, perhaps, even colonization. Eventually, who knows, humans might be exploring other galaxies as well. It is the expansion upon these necessarily murky ideas of what else man's destiny will include that often engenders the greatest excitement.

Chapter IVTWO PESSIMISTIC SCENARIOS
PART I: THE CHINESE SOLUTIONA. 1976-2000The New Class ideology

During the 1970s a social phenomenon arose, spread rapidly and became especially strong in most of the technologically advanced non-communist countries. Its influence was expressed through (a) a rapid growth of environmental and conservation movements; (b) a growing concern about the large economic differences between the richest and poorest classes within each country as well as the differences among nations (e.g., the North-South dialogues resulted from this concern); (c) a neo-Malthusian doctrine which opposed economic growth in the wealthier nations and actively opposed most large industrial--especially energy-supply--projects in those countries; and (d) an increasing transfer of responsibilities to the innovators of new products or processes that required them (by governmental regulations) to furnish prior proof that any new risks which arose would be insignificant, plus the responsibility of paying damages if they were wrong (i.e., forcing them to obtain adequate amounts of long term risk insurance if it was available--or to assume the risk themselves if it was not).

This new ideology appears to have started during the 1960s in the U.S., developed and spread rapidly during the 1970s and 1980s, and then led to a persistent struggle to improve the Quality of Life (QOL) in the industrialized nations even though it also implied a bare minimum of economic growth during the balance of the century. To many observers of that era the ideology had a strong quasi-religious overtone--that led to a kind of "modern-day Zealots," some of them claimed. From our historical records it was not always--or even usually--clear how an improved QOL for society was to be defined or interpreted, as one group's perception of such an improvement often implied restraining or lowering another's standard of living. The argument that this ideology also created disincentives for hard work was brushed aside by its adherents, who were sometimes referred to as the New Class. Work according to them was to be made desirable, not hard. Consequently any required hard work should receive extra compensation. The New Class ideology made it clear that health, safety, education, economic security, a more equitable distribution of income, and greater opportunities for a happy life in a clean environment for all citizens should be the primary goals of government. Indeed, this ideology was, in principle, to be extended to help all developing countries--especially the poorer ones--gradually to improve their QOL until their's were on a par with those of the developed countries.

Technology was to be kept both useful, by providing for material needs, and controlled, to keep it from creating any significant new risks to health, to the environment, or to the capacity of nature to provide resources. That technological progress continued to take place under these circumstances was probably due to the fact that unusually powerful tools already existed. The solid state computer, the laser, instruments for automated chemical analyses, automated production machinery, and a revolution in the basic sciences and in engineering resulting from the computers and instruments had come into being during the 1950-1975 quarter and gained such strong momentum that it continued to develop despite the growing anti-technology resistance from the New Class. The full impact of this technological revolution was so vast and complex that in those years relatively few scientists fully appreciated its potential. Thus, the increasing technological development in the most advanced countries was able to compensate for a changing social system which gradually was to drain (from technology) its funds and its brains, and to make commercial applications to innovative products and processes increasingly cumbersome.

After 1990 the New Class ideology continued to strengthen in the OECD nations (including Japan, but less rapidly), and even started to affect the Soviet Union. However, Third World nations remained relatively impervious to its temptations. They accepted some of the obviously desirable environmental changes and gave lip-service support to the New Class goals where it was to their advantage. Within the OECD countries the low economic growth rates of the 1980s and 1990s were rationalized by the New Class as a required worthwhile sacrifice to achieve their main purpose--an improved QOL over the long term for all nations.

However the U.S.S.R., China, and Brazil were among the relatively successful large (non-OECD) countries that effectively resisted New Class concepts and continued to stress economic growth and technological progress--each in its own style, of course. Also, each of these countries was destined to surpass the United States in space development within the next 40 years--a direct consequence of these ideological differences.

The great concern about energy shortages within most of the developed countries abated somewhat in the 1980s for three reasons: (1) an economic slowdown in the OECD countries and a reasonably successful energy conservation effort (from 1978 to the year 2000 total energy demand of the developed nations increased on average only 0.5 percent/year); (2) by 1985 OPEC found itself with an enormous excess production capacity and considerable infighting or elbowing for markets occurred--a "game" which eroded their cohesion as well as their income; (3) very successful exploration for oil and gas occurred in several developing countries--especially in Brazil and Mexico--and usually with some financial help from the wealthier nations. The reduced demand for petroleum, and its increased production capacity meant that available supplies would be more than sufficient to meet the world's needs until newer energy technologies became important contributors early in the 21st century. The abatement

of the energy crisis was interpreted by the New Class as a victory for their ideology while their opponents in the industrialized nations grumbled about forced conservation measures, inadequately sized autos, and--most of all--persistent economic stagnation, a trend which the New Class favored (and pointed to the relaxed energy situation as evidence to vindicate that policy).

U.S. Economy

Although the GNP in the U.S. increased 50 percent during the quarter century, that represented a growth rate of less than 2 percent and a per capita growth rate that nominally was slightly positive, but which in terms of material consumption was slightly negative--but which was also, according to claims from the New Class, was more than offset by an overall improvement in the QOL.

The U.S. space budget during the last quarter declined, in real terms, by about one-third to \$2.4 billion (1975 dollars). Funding of science and technology also eroded, especially during the 1990s to about 85 percent of the 1975 level. Innovations became very threatening to many industries as available risk insurance was inadequate or too costly. Also, where government licensing and/or permits were required, the time and effort involved in obtaining them continued to increase, much to the dismay of private industry. For example, after 1990 the estimated time between the initiation and completion of a coal-fired electric power installation increased to 15 years--compared to 3-4 years in Brazil, and 8 years in Japan (in which only a decade earlier it had also been less than 4 years). As a result higher unemployment and lower salaries prevailed in most technological areas of the U.S. By 1990 the beginning of a reverse "Brain Drain" was observed--unemployed technologists looked for and found opportunities in the growing Third World countries as stagnation continued in the U.S.

Even highly successful space projects generally did not create confidence in similar outcomes for future programs, especially because their long term economic benefits could not be "proved" in advance. For example although the LANDSATS were known to be highly useful doubt about the value of future improvements constrained the expansion of that effort. The remarkable success of COMSATS became embroiled in national debate over the value of excessive communications--in any event they were left within the province of highly-regulated private ventures. The Advanced Space Shuttle program, proposed in 1988, was buffeted about for 3 years by arguments about the growing risks from the impact of spacecraft launches on the upper atmosphere. It was postponed indefinitely in 1991.

The U.S. space program probably would have been an earlier casualty of the emerging social system had it not, astonishingly, been spectacularly successful. Still, it was a rare year that its budget was not eroded

C-2

in real terms, although the continuing inflation often made it appear to be constant or increasing.

The space program increasingly was oriented towards current needs on earth by deploying satellites to improve communications, monitor pollutants, predict weather, provide accurate navigation, prevent sea and air collisions, find mineral resources, predict earthquakes, assess agricultural production, determine water resources, etc. Although these tasks generally were performed better than was anticipated, that did not keep the space budget from falling. Each success tended to become a routine service and was soon forgotten by the non-technical public. These services, once established, were thought of as "free"--that is, it did not require money to be spent out of pocket in order to get a weather report or a measurement of atmospheric ozone. The value of the satellite-based communications system was buried in the telephone bill, the inflationary changes, and the complicated and the peculiarly American system of charges for television services. It was difficult for the public to appreciate the relative cost-effectiveness of the space program because of its inherent complexity, its dependence on government support, and because expressions of hostility against the risks created by science and technology increasingly came into vogue.

Nevertheless, there were some impressive new successes. The Solar Sail was shown to be effective as a spacecraft which, in 1993, after a rendezvous with a new Comet, was sent to observe the planet Mercury from a low orbit. A large (250-foot diameter) Antenna was constructed in space in 1997, 1 year after a Modular Space Station was placed in LEO (with 4 people aboard). Roving Landers were successfully landed on the moon (1995) to gather scientific data and one was to be sent to Mars in the next quarter. A small Space Industrial R&D facility with a 20 KW Solar Power Satellite was established in 1998--but the Soviets were well ahead of the Americans by then.

Particularly disappointing to the space specialists was the refusal of the government to fund their more ambitious projects such as the Advanced Space Transportation System, a program for colonizing the moon, or a life science program for establishing the feasibility of permanent space colonies. An advanced transportation system, of course, would have been tantamount to a long-range commitment to a large and growing space program. That was not consistent with the new ideology.

Although those attitudes discouraged space enthusiasts, space professionals, and, indeed, most of the scientific and technological communities, the American public barely noticed it. Of course New Class leaders were pleased and claimed that humanity had been protected from potentially great risks. In the late '90s many of the more aggressive New Class leaders within the OECD nations concluded that the time was ripe to start bringing their ideology to the more successful developing countries as well as the centrally-controlled economies--especially the U.S.S.R. and China.

Changes in Brazil

The most spectacular economic successes during that quarter century occurred in some of the developing nations; the outstanding example was Brazil. A desire for wealth and power which had been lit in Brazil during the 1960s and 1970s faltered in the early 1980s and then became rekindled into a unquenchable national passion that overcame obstacles such as inflation, worldwide recession, energy shortages, heavy indebtedness, and regional illiteracy-- obstacles which were effective barriers to many other nations. A major key to that success was a stable government, after 1985, which was strongly oriented to entrepreneurship from the private sector. As a result the Brazilian GNP rocketed from about \$110 billion in 1975 to \$750 billion at the end of the century. Their economic success was greatly assisted by the financing available from the developed nations and by the technologies brought to them by large supra-national corporations. These corporations found an increasing symbiotic relationship with the Brazilian passion for growth, after which the "honeymoon" became a protracted one.

Brazil's educational system acquired a strong science, technology and business orientation. Because of profitable industrial growth and the encouragement of foreign capital investments, but also from the rapid exploitation of huge new oil and natural gas reserves, which luckily were found during the '80s and '90s, Brazil was able to improve its balance of payments rapidly. The Brazilian universities also developed into very high quality institutions and soon were enticing the world's best brains with high salaries and guarantees of adequate research support. The use of English in all technical departments of higher education levels soon became customary as foreign scholars, lecturers and professors, who were allowed to teach in English or in Portuguese, almost always chose English. As high technology industries received very favorable treatment after 1985, foreign investment--especially from West Germany, Japan and the U.S.--continually increased thereafter.

More because space development was a symbol of technological progress than for its commercial potential, the Brazilians began a serious space program in 1990 which grew 10-fold in 10 years to a \$1.2 billion level, a level that at century's end was within striking distance of the U.S. space budget (\$1.8 billion). This growth became possible because many space scientists could be recruited from Europe and the U.S. Later, while celebrating the turn of the century, Brazil committed its space program to at least a 6-fold increase during the next 25 years, a level that--if attained--would be roughly equal to the year-2000 budget estimated for the Soviet Union--the acknowledged world leader in space at century's end.

Awakening in China

Another "sleeper" in the economic growth "race" turned out to be China. Because of its customary policy of self-reliance China's average 8 percent growth rate during the last 15 years of the 20th century was

seldom noticed except by professional China-watchers. Although foreign trade with China was growing, it hardly compared with that of other large nations. Consequently, the developments within China tended to be overlooked or soon forgotten. By the year 2000 its GNP had reached \$1.25 trillion--a very respectable amount and substantially greater, if less flamboyant, than Brazil's \$.75 trillion. Of course, China's per-capita GNP was only about \$1,200. But the population had stabilized and its expanding infrastructure had been kept reasonably well balanced over time.

A quiet Chinese "passion" resided in the population's traditional belief that their "cultural superiority" would enable them, in time, to succeed wherever they chose to compete. It was clear to some observers that they were making excellent progress in technology, economic development, science, and in space projects. Evaluations of their QOL were more subjective and depended strongly upon the values and data selected by the analysts.

Thus, it was not obvious that the Chinese were destined to become an envied culture in many ways. They had been admired for decades because of their independence, self-assurance, their conviction of cultural superiority despite prolonged earlier poverty, and their refusal to accept (let alone ask for) outside assistance--even during severe natural calamities. Thus, their interest in space development, which to them was a symbol of progress, was only natural. The pace of their space program, of course, had to be determined in competition with other demands, but their attitude was simply that China would become the natural leader there, too--as in all important cultural developments--in the course of time. The ideology of the New Class had almost no effect upon the Chinese who interpreted it merely as a temporary manifestation of struggles within confused inferior cultures, going nowhere.

Particularly noteworthy, however, was the Chinese space program which first became newsworthy in 1988 when a COMSAT was launched into orbit. After that their progress was rapid. By century's end they had launched 140 spacecraft (with only 6 failures) and were reliably reported to be testing an advanced reusable launch vehicle which was designed to perform at least on a par with the U.S.S.R.'s best, the KUPAROV, an automated reusable space "freighter."

China's budget for space projects, though not publicly revealed at the time, had been increasing by about 10 percent annually in the 1990's. By the year 2000, therefore, it exceeded that of the U.S. Space development in China was less flamboyant than that in Brazil, but was more secure as it did not depend upon foreign assistance. There were at least a few observers who at that time projected the long term Chinese effort in space to grow almost twice as fast as their GNP and who thought it might even reach the impressive level of \$30 billion/year by 2025. (This forecast, as we will see, turned out to be premature.)

Progress in Japan

After 1990 the Japanese were judged by some investigators to be the most technically competent nation of all, especially after making allowances for their late start and a lower GNP/capita (than the U.S.). However, their earlier goal of achieving parity with the U.S. in GNP/capita by 1985 was not achieved until 1994, and even then it was more because U.S. growth had slowed to about a 2 percent rate--not because the Japanese were able to maintain their earlier momentum. Their economic growth averaged 5 percent in the quarter; that was high by world standards but only about half what they had achieved during the prior quarter century.

Psychologically the Japanese were strongly affected during this period by the habit of poor-mouthing their natural resource situation ("we are only a crowded small country with insufficient energy or mineral resources of any kind," etc.). They had come to believe that they were vulnerable, despite impressive evidence to the contrary--that they were rich and were getting richer steadily. Feeling insecure, however, prevented them from making substantial investments in a long term space program, the economic advantages of which were obscure to their principal decision makers.

Of course, there were many other relevant factors, not the least of which was the inroads made by New Class concepts--especially after the middle '80s when they felt the strong pressures of that ideology from other OECD nations and from their own intellectuals. In many subtle ways it was to have an increasing impact on Japanese culture. In particular, without much pressure from their own population or from their principal trading partners Japan's space program languished. It was to remain in a relative torpor until the commercial utility of space investments became obvious--that change was to occur only after 2025.

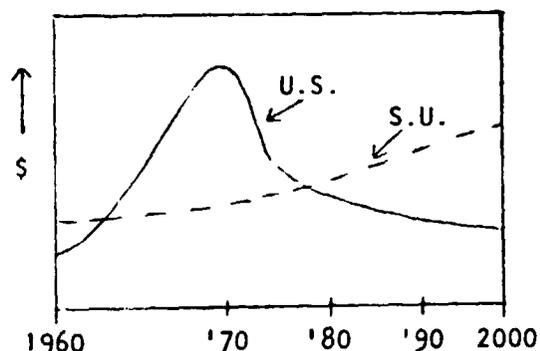
Space Program in Western Europe

From its inception the European Space Agency (ESA), whose principal contributors were West Germany, France, the U.K., and Italy, struggled for vitality. Beset with problems of different languages, differing economic needs, and a bewildering array of public perceptions about its role or utility, it was perhaps remarkable that ESA was successful in its Space-lab project with NASA in the early 1980s. Despite this success further attempts at a unified European program proved to be too difficult in a period when R&D in both science and technology were experiencing declining investments. ESA was abandoned in 1989 although each country maintained some kind of space program thereafter, but each of these continued to struggle with low funding. Only West Germany's program kept pace with their GNP, but it was unimpressive by American, let alone Soviet, standards.

Space Progress in the U.S.S.R.

Despite the Americans' spectacular early successes in space (the astonishing Apollo lunar landings, the miraculous Viking robots, the eminently successful Space Shuttle and Spacelab, as a few examples) the Soviet tortoise was to be well ahead of the American hare by century's end. That outcome was clearly signaled during the decade following the Apollo program as shown in the graph below comparing the U.S. space budget over time with the Soviet one.

GRAPH



Both the Soviet economy and its space program grew slowly but steadily during the quarter at about a 2.5 percent rate. As a result by century's end Soviet expenditures in space were estimated to be almost 3 times those of the U.S., and their advances in space science, space exploration, and the commercialization potential of space had become impressive to space analysts. Even though some of the New Class ideology had rubbed into the Soviet way of life, and affected the growth rates in both their economy and in space more than would have been anticipated prior to the '80s, the impact was relatively small. The simple fact was that without significant competition from the U.S. the Soviets became the Giants in space development well before the year 2000.

After 1986 European and American space buffs were to be subjected to a sequence of Soviet space "victories" which depressed their morale. By year-2000 the Soviet Union had successfully completed the following space projects:

- SSTO 100-ton payload unmanned reusable "freighter"
- Solar Electric Powered (SEP) orbital transfer vehicle
- Permanent lunar station (6 people)
- Lunar observatory and scientific laboratory
- Kilometer-sized space antenna
- Space industrial facility (with 8 people and 150KW)
- Space station in LEO
- Advanced nuclear space "tug"

Soviet-American cooperation in space technology which had worked reasonably well during the '70s began to slip in the late 1980s as the imbalance in the arrangement became clear. By 1990 it had effectively lapsed except for desired voluntary disclosures. Although some people imputed military motives to the Soviets, this was later shown to be secondary. The Soviet Union had simply preferred to maintain a growing advantage over the Americans. The tortoise was finally enjoying its victory over the hare.

B. 2000-2025

Brazil

The Brazilian economy roared into the 21st century and became the envy of the many nations. It averaged an 8 percent growth rate over the first 10 years, bringing its GNP to \$1.6 trillion. But after 2010, economic difficulties began to accrue which slowed its growth considerably. First, their largest oil and gas fields, which were developed late in the previous quarter, had become substantially depleted, and their oil income decreased rapidly after 2010. This forced them into greater borrowing to finance much of their expansion goals--an option which soon brought severe credit limitations, and affected their economic growth over the balance of the quarter. Furthermore, their growing foreign exchange problems after 2010 first stopped and then reversed the flow of external (and expensive) brain power toward Brazil--unfortunately before the hoped-for advances in their education system were completed. Thus they were unable to produce the indigenous competence needed to assume the tasks which had been performed by foreign experts.

Their booming space program which by 2010 had reached a budget of over \$5 billion, "the largest in the free world,"--as the Brazilians were not slow to proclaim--was affected by growing economic stress after 2010 and, although it continued to increase, the growth after 2010 averaged only about 3-1/2 percent for the next 15 years, ending with a respectable, although not spectacular, \$8 billion. From the beginning that program had a dual purpose: (1) to help develop Brazil's science and technology capability, and then to enhance their economic development by exploiting space industrialization as well as the anticipated spinoffs, and (2) to exploit the commercial utility of earth-oriented satellites. Later, in 2017, they promoted the world's first serious commercial space tourist enterprise. But the space industrialization and tourism both ended the quarter much less successful than the Brazilians' earlier expectations.

The principal problem in their space industrialization program was that its commercial success depended to a large degree upon their ability to export its innovative products. But in their enthusiasm they had, too naively perhaps, refused to understand the depth of the resistance

in the developed (and now largely post-industrial) world to innovations in technology--especially from abroad. Thus, although a flood of new and, to them, exciting products and processes emanated from that program, foreign consumers did not eagerly run to buy these products and services. Slow acceptance and long procedural delays made the commercial aspects of the program very awkward as the economies of scale needed for efficient production often required expensive, large-volume space installations. This resulted in a number of costly abandonments during the quarter, as well as broken dreams.

The space tourist industry was formally started by Brazil in 2017. Initially the cost for a 3-day LEO tour was about \$250,000. Business was brisk for about five years and then flattened out just as a greatly expanded capability was being installed. Supporters of the New Class had condemned such costly "gaudy" expenditures as inconsistent with their ideology--a view which after the first few exciting years increasingly restricted the available foreign business. However, a careful study revealed that the most significant factor was that about 10 percent of the space travelers had been significantly affected by the SAS syndrome associated with the transition to weightlessness, and by the subsequent stresses from reentry and readjustment. This led to a bad press and tended to discourage the interest of other potential space tourists. Indeed, the Brazilian authorities had been all too casual in their attitude towards the physiological aspects of this new venture. They had decided to treat it as a strictly commercial venture--a decision which in effect left the establishment of criteria for space traveler selection and preparation in private hands. Unfortunately, the franchised corporation in its early enthusiasm (and perhaps also from financial pressures) was less than adequately careful in its approach to the physiological aspects of space tours. By the end of the quarter the industry's installed capacity (50,000 tourists/year) was double the demand for seats. Some enormous losses resulted that were to make future investors quite wary of commercial ventures in space.

U.S.S.R.

The Soviets entered the 21st century as the world's space giant by virtue of a budget estimated at about \$9 billion for the non-military program. Their space industrialization effort was directed toward furnishing new products and processes for Soviet industry. Even though they were successful in creating many innovations which were interesting, even exciting, they made the mistake (common to new Soviet commercial ventures) of overestimating the ability of their traditional industries to respond rapidly. The sluggishness of internal Soviet commerce was usually only experienced directly by those who tried to encourage change. Except in the production of new scientific or military equipment (and not always then) the resistance of the Soviet system to innovation was profound. In a Soviet factory proposed changes generally promised little but trouble to the commissar of production, making him loath to give up a satisfactory routine for something new--especially when

failures generally brought great punishment, and successes small rewards. Thus, the Soviet space industrialization effort--like that of the Brazilians, but for different reasons--encountered a severe marketing problem which greatly impeded its potential development.

Because the Soviet science and exploration program, was excellent, however, they easily maintained their lead in these fields during the quarter. The Soviet space budget continued to grow but the average rate of growth rarely exceeded the "standard" 2.5 percent. By the end of the quarter it was estimated to be \$18 billion, barely ahead of the Chinese who had made significant progress and had the second largest effort. A lesser efficiency, however, affected their nominal budget advantage considerably.

China

Economic progress in China remained steady, if not spectacular, during the quarter century. The Chinese also maintained a well-balanced growing space effort suited to their own needs. In addition to their earth-oriented satellite program, they concentrated on adapting spinoffs to utilitarian purposes. Interaction with the space programs of other nations was kept relatively subdued, although their specialists were present at every international conference related to space developments. At these gatherings Chinese contributions, while few, acquired a reputation for unusually high quality.

During this quarter their space budget--keeping pace with their GNP--grew at an average of 5 percent annually. By 2025 it exceeded \$17 billion. The effectiveness of their effort was clear to all space scientists--some of whom stated that China's program glowed with a quiet brilliance that often was not observed because of the minimal communication and lack of publicity beyond their borders. But by the end of the quarter a Chinese presence was observed almost everywhere in space where other countries had been successful. The Chinese Space Transportation System was well balanced and efficient. Their array of space tugs included nuclear propulsion systems as well as ion engines, solar sails, metallic hydrogen thrusters, and beamed energy systems. They had a large lunar base, a 6-man Mars station and were studying the asteroids with both manned and unmanned vehicles. Their contributions to space astronomy during the quarter had on several occasions startled the scientific world with new findings (for example, the first reliable description of the distribution of black holes in the galaxy by type, size, and density).

JAPAN

During this quarter Japan remained the richest country in terms of GNP/capita. It had gradually changed into a consumer-oriented society--and with growing elegance. As the lack of a widespread international commercial

interest in space industrialization (except COMSATS and other earth-oriented satellites) was apparent, the Japanese were content to participate in the scientific and exploratory aspects of space in cooperation with the Americans, the Brazilians and others. Also they preferred to maintain their relative economic position rather than to attempt to further out-distance other nations. They contributed a rather large fraction of the space tourists who patronized the Brazilian system and appeared to be less disturbed than others by problems associated with weightlessness.

The New Class ideology, however, increasingly affected the Japanese culture. Thus, demands for sharing more of their wealth with the poorest nations were strong, both from within their culture and from outside. These internal ideological conflicts combined with some growing altruistic motivations to reduce their economic growth rate to 3 percent by the end of the quarter (averaging 4 percent). Still their per capita GNP reached an impressive \$30,000.

U.S.

The U.S. had been in a deliberate prolonged economic recession since 1989 that had been justified as the price of an improved QOL. But by 2015 the QOL concept was not much clearer than it had been in 1976. The social conflicts between the productive and unproductive segments of U.S. society remained severe. The U.S. had lost its position as world leader in most innovative areas of international importance as well as much of its earlier competence in organizing and managing industry and in applying innovations. Its scientific contingent was competent--but relatively small and isolated--and tending to emphasize theory more than experiment because of meager funding. During the 2015-2025 decade it also became evident that the New Class was becoming an "old class" and that its ideological grip was fading. As the quarter ended it was not clear what new direction(s) the country would take but there was a sense of imminent change.

The federal space program by 2025 had dwindled to the point where it was maintained at a mere \$1 billion annually, with somewhat more than that (about \$2 billion) being invested by private industry which had taken over most of the commercial earth-oriented ventures, COMSATS, LANDSATs, SEASATs, etc., and the small SI program which was developing only very slowly as an advanced transportation system (mostly constructed by the Brazilians) was just being phased in through an international joint venture basis (involving Brazil, West Germany, Japan, France and the U.S., as well as private industries from each country).

Europe

New Class ideology continued to pre ail in Europe. The costs of providing clean energy, achieving and maintaining adequate environmental purity, and providing welfare assistance in and out of the EEC had severely drained their resources--especially as their interest in new

technologies had weakened as well. W. Germany had a stronger interest in space development than the other European countries but found it difficult to maintain, for political reasons, even though it was not large. Economic growth in Europe averaged about 2 percent during the quarter; about half of that was donated to foreign aid. Fortunately for Europe and the U.S. the Soviet Union did not develop its military appetite during that period.

C. 2025-2076

China

Strangely, perhaps, the quiet but pervasive Chinese confidence in their "inherently superior" culture may have been the most important factor which led to their preeminence in science and technology--and in space development, in particular--during the last 50 years. In retrospect, it appears that the Chinese have been more egalitarian, in a national context, than most of the countries which adopted the New Class ideology. Indeed, in many countries it often was accepted only in a casual or routine manner, like that of a "Sunday morning Christian."

Early in this century, however, the Chinese had learned to couple their egalitarian economic distribution system with a productive one which emphasized excellence. They had, in principal, always included environmental protection as part of their social system--even well before the U.S., for example, passed its first National Environmental Policy Act (1969). The need for an appropriate balance between cleanliness, in the larger sense, and production was more ingrained in the Chinese than in the other countries and consequently made it easier to resolve conflicts between economic production and environmental protection as they arose.

Economic growth, per se, was not the overriding motive in China as it once had been in most of the "free world" countries. Rather they chose to emphasize, unheralded, their strong admiration for wisdom, competence, and excellence in all forms. Wealth was a great potential aid to the achievement of progress in this context but wealth, in itself, was not admired as a measure of success. Moreover, their political system (which made a gradual transition from communism in the 20th century to a full democracy by the year 2040) discouraged the accumulation of individual wealth, thereby effectively removing it as a primary personal goal. But general increasing wealth for the country--also in reasonable proportion for the smaller regions, and for local communities or industries--became expected more than desired. Of course, the funding of specific projects was always a struggle, and in retrospect the results almost always were suboptimal. Still, the sustained common goal was to promote the greatness of the Chinese culture through progress in every important attainable way: arts, science, technology, education, health, sports, etc.

Although the reasons even now may not be completely clear their economic system continued to function unusually well. The Chinese

GNP grew steadily after 2025--roughly at about 6 percent annually in real terms--as best that could be measured. By the year 2050, after about 65 years of continuous and sometimes rapid growth, they were rich in a world sense, having passed all nations, except Japan, in GNP/capita. But with a population of 950 million people their GNP was almost \$20 trillion in that year.

An unanticipated surprise, however, was their huge space budget which, increasing at an average rate of 9 percent from 2025, reached \$150 billion in 2050. By then the Chinese had become the outstanding world leaders, not only in space technology but in most branches of science and technology. Moreover, it is now clear that after 2050 it was unlikely that any other country would or could surpass them in less than a few decades. Their wealth, population, GNP, scientific establishment, technological competence, and most of all, momentum made effective national competition unlikely for the foreseeable future.

Competition, however, was no longer a key issue to them. By mid-century the Chinese culture had evolved to the point where it was quite secure, where its exact national boundaries were no longer a major issue. Boundaries became accepted as the result of an historical set of accidents rather than the contentious 20th century view which made a cause celebre over each debatable acre. After 2025 their culture began to develop a relatively intimate exchange with the rest of the world. Results were sometimes slow in coming, but they were predictable. China had become a successful role model for both the developing and the developed countries. Naturally, there were attempts to follow that model as best it could be perceived and understood, but, it was difficult. Societies have rarely changed rapidly in predictable ways. Attempted societal change is generally resisted and usually misunderstood by most citizens. However, the Chinese model did exist, and the communication systems available almost everywhere in the world made the detailed operation of this model easily accessible, if not always easy to comprehend.

Several important international developments had already occurred or had begun to occur by 2025. First, it had become clearly understood, world-wide, that widespread poverty in any regime was a sign of deep social sickness within that society. Moreover, there was always an escape available, in principle. The wealthy countries of the world--especially China and Japan--were ready to assist any country or culture in which the desire to eliminate poverty was perceived to be genuine. This attitude had for several decades existed on a smaller scale but by the year 2050 it had become a pervasive standing commitment to any society in which elimination of poverty could reasonably be achieved without military intervention.

Indeed, military solutions to perceived or traditional international issues had become less and less important over the first half of this century. After 2050 they essentially disappeared. There were several principal reasons. First, Japan's remarkable early success had clearly

demonstrated that land area constituted an increasingly smaller fraction of any nation's real wealth, and therefore was relatively unimportant for economic prosperity. Second, and perhaps more significant, was a medical capability, fully developed shortly after the year 2020, to prevent any child from being born with any serious genetic defects--including any which could seriously impair mental or emotional functions. Although application of the technology was only slowly accepted for a decade or so, by 2050 it was rare for any child to be born with any such handicap. Thus, the concept of a clean environment had been extended to include genetic "cleanliness" and it helped to stabilize world society.

Another reason for rapid decline in attempted military solutions was a fading interest in such approaches among the leading great powers: China, Brazil, the U.S.S.R., Japan, the U.S.A., West Germany and Mexico. China had even startled the political world in the year 2028 by renouncing any formal claims to Taiwan--and at a time when the Island could probably have been retaken readily. The surprising result since then has been a rapid gravitation of the Taiwanese toward China and a great amount of reunification sentiment in Taiwan--a possibility that China was no longer eager for, primarily because of the cultural disparities which had arisen out of the long separation.

Thus, in 2050 the stage was set for cultural changes in the world towards the Chinese model--which itself was evolving. The next 25 years was to witness the world's most dramatic evolutionary periods, one which led to our current society. The notion inherent within former egocentric cultures, that a democratic society should be oriented to maximize an individual's QOL and his personal goals wherever they may lead, was eventually found to be inadequate because of its inherent tendency towards internal disruption, fragmentation, or even anarchy. A basic conflict arises from its implicit encouragement of freeloaders, who over time may approach or become a majority, and through their political influence which (in a democratic political system) places an unacceptable burden upon the rest of the society.

Some of the countries which had been dominated by New Class ideology began to emerge from its influence well before mid-century. During the decade of the 2040s the trend accelerated rapidly. Now the New Class phenomenon is only history; it has been replaced by the theme of the U.S. Tricentennial celebration: Rapid Progress, through Knowledge and Wisdom.

The total world investment in space development this year will be about \$1.2 trillion--\$500 billion from China's space budget, \$300 billion from reinvested income from space production (2/3 Chinese), and \$400 billion from private investment and the budgets of other countries of the world. Perhaps what is most important about current world society is the recent sense of harmony in all science and technology programs indeed in the world's interest in knowledge, in cooperation, and in establishing desirable goals for mankind. The successful Chinese space colonies at L-4 and L-5 the multi-national ones on the moon, and the

recent large international scientific laboratory on Mars, coupled with the impressive, rapidly growing space industries, have given the world a new vision about its potential in the future. This change has also been greatly aided by the Chinese space travel and tourism program.

That program was started in 2030, shortly after the earlier Brazilian venture became stagnant. About half of the Chinese tourists during the early years were selected from the list of qualified Chinese applicants by a lottery. Since that time the industry has grown rapidly and a modified lottery system is still being used. After 2040 citizens from all countries were invited to use the Chinese space transportation system, which has remained the world's largest by far. The growth of that system is shown in the table below.

Table 14

CHINESE SPACE TRAVEL DATA

TOURISTS (THOUSANDS)

<u>DATE</u>	<u>CHINESE</u>	<u>FOREIGN</u>	<u>TOTAL</u>
2040	20	1	21
2050	250	50	300
2060	3,000	1,500	4,500
2075	20,000	12,000	32,000

Not only have the numbers of tourists grown rapidly but the duration and nature of the available tours have changed. A typical tour today lasts 30 days, compared to 7 in 2040, and the itinerary generally includes a week on the moon and a visit to at least one of the space industrial installations--in addition to accommodations in the special LEO facilities for tourists (hotels, hospitals, museums)--and to a colony at L-4 or L-5. However, the cost for a 30-day tour is less than that for a 7-day LEO tour in 2040.

BRAZIL

Early in this century the course of history appeared to have given the Brazilians a unique opportunity to become the world's model for successful development. However, the model which shone brilliantly for about 40 years was not soundly enough based to maintain its momentum. Of course, the Brazilians did extraordinarily well during that period and became one of the world's most advanced countries in several senses, perhaps the most advanced for a short while. One of their problems,

their large need for income from natural resources, had not ended when their more profitable resources were near exhaustion. That forced them once again into heavy borrowing in an attempt to maintain economic growth. Secondly, they had become locked into international economic ventures that drained their resources. As a result their economy became stagnant, or at best growing weakly; that in turn created various impediments to their growth. Finally, the 40 years between 1975 and 2015, that gave them an opportunity to become a world leader in economic and technological strength, were simply insufficient for the required social changes to occur. For that they would have needed at least another 25-45 years of rapid growth in order to develop their infrastructure sufficiently and to create appropriate long-term traditions.

The Brazilian culture of the 20th century was basically oriented toward economic growth and employed technology and capital as its principal means of achieving that goal. Their initial successful gamble to develop economically on borrowed funds, their subsequent successful efforts to exploit their natural resources for additional capital, and their bold program to import both the technology and the technologists gave them a tremendous opportunity, but as we now know it was insufficient as a self-sustaining arrangement. After their principal exportable resources were largely used up and international borrowing had reached practical limits they discovered that their conversion to a modern industrial society was still incomplete. Then they had to endure a long period of adjustment from about 2015 to 2050, during which their venture into space travel floundered and their economic development programs in space as well as on earth became relatively flat.

Their excellent early space effort, which reached the \$6 billion level in 2010 and far exceeded the American budget, at that time constituted the principal hope for space development among the non-communist countries. However, this budget grew only to about \$9 billion during the next 15 years. These sums were sufficient for a variety of developments including an advanced Space Transportation System, an early Space Industrial effort and a very respectable science and exploration program which included a lunar colony, an advanced modular space station in LEO, and a manned one in geosynchronous orbit.

however, the growth of their space program after 2010 was primarily dependent upon the successful commercialization of space travel and tourism. They failed, in part because the tourist program was not successful, as discussed earlier, and because the space industrialization program required the support of a vigorous and growing world interest in new technology. Unfortunately for Brazil during those years most of the developed world remained in an ideological torpor which resisted innovations in technology and thus hampered the commercial space effort.

Therefore, it was not until the middle '30s when the Chinese model began to affect other nations significantly, including Brazil, and

opportunities for growth again appeared, that the situation again began to change. By 2050 the Brazilian economy once again was booming; their space budget reached \$25 billion and was growing rapidly. During the most recent quarter it averaged a 5 percent growth and reached \$80 billion only last year. Also, neither Brazil's economy nor space program is now dependent on outside assistance, in the sense that it was at the turn of the century. Of course, the world is also much more cooperative now and national commitments to the world space program appear likely soon to become "standardized" as the program becomes more international or, as some expect, supranational.

U.S.

As this year's Tricentennial celebration has begun I am at once pleased at the recent rapid progress and the renewed commitment to space development by my country. Looking back I am still surprised at the astonishing pause in activity that the U.S. and many other countries experienced for about 65 years, 1975-2040. Perhaps something valuable was gained through this experience--perhaps it had to happen to prevent a disastrous outcome. That is an unknowable and wishful statement at present, but perhaps it can be analyzed in coming decades. We have learned a great deal about societal trends, social forces, and human behaviour during the last century, and perhaps we will be able to solve those harder problems before long. While Americans are grateful to the Chinese for having helped to pull our nation out of a profound slump, it is also clear that it would have occurred eventually by some other means. The Chinese themselves were the first to make that point clear. But sooner is better than later. To have "lost" another 50 years in the "doldrums" would have been unfortunate for perhaps billions of people.

PART II: THE TRIUMPH OF THE GARDEN* (2025-2075)
 (A PESSIMISTIC SPACE DEVELOPMENT SCENARIO)

From the viewpoint of the world's space buffs the first quarter of the 21st century was a relative "disaster." Except for the flashy effort in Brazil which was somewhat in disarray at the end of the quarter and the period of steady progress in China, there was little for them to celebrate in the rest of the world. Indeed, most of the world seemed to be inward rather than outward bound. Science, technology and industry were primarily being harnessed to fulfill perceived material and environmental needs and to make the world a very safe place, one in which people could devote themselves to traditional artistic, cultural, social, and political pursuits with a minimum risk to health or safety.

The potential rewards of space development and space travel had been debated and found wanting--indeed had been judged to be too costly and risky, especially where it involved manned programs. Moreover philosophical and religious polemics appeared in the communications media more and more often which asserted that man's attempt to scatter his seeds ever further into space was an incipient new form of pollution, if not desecration, of the purity and beauty of the universe. Concerns about orbiting weapons in space, threats of pollution or damage to the upper atmosphere, the potential for space warfare, and the inevitable collisions which would increase space debris and occasional space accidents were all cited as evidence of the evil potential of unfettered development attempting to slip out from the controls of reason which had only recently been established on earth.

The unfortunate experiences of the Brazilian space travel and tourism venture furnished extra weight to the arguments against expanding space development. Also the tendency of the human body to adapt to new environments had created stresses among some tourists that resulted in unpleasant, if temporary, physical consequences with symptoms of vertigo, dizziness, palpitations, weakness, headaches, and high blood pressure. Some of these symptoms were believed to be amplified by accompanying anxieties--especially when real or fictional stories about prior space-related health disturbances were discussed or recalled. Naturally, the worst of these stories received the most publicity and distorted the public's ability to make accurate judgements about the risks involved.

Brazil

The bankruptcy of the first Brazilian space tourism venture had a profound effect upon other commercial aspects of their space program.

* This variation of the previous scenario begins in the year 2025. Its first 50 years are identical with the prior scenario beginning on p 133.

Capital became scarce as the risks were believed to be high and the government became unwilling to subsidize such ventures. Indeed, because of the losses in space industrialization ventures and a struggling economy which had racked up huge debts, the Brazilian space program was severely slashed during the 2025-2035 decade and it eroded further after that. By 2050 its funding had fallen to a \$2-billion level and it had essentially become an "orphan" agency in the government--one of low prestige, stagnating in a no-growth maintenance mode.

Brazil's troubles in space were only a small part of deeper economic difficulties that had begun before 2020. The need for new capital after that year became more pressing as locally available funds were drying up. Brazil's ability to entice foreign technical experts had ended and the previous in-flow started to reverse. Foreign scientists and technologists attached to space projects were among the first to be phased out--and the trend was soon quite clear. All foreign technological personnel whose economic security in Brazil was threatened faced a very uncertain future since they generally had to return to home countries in which their kind of expertise was already in surplus. Of course, there was no real threat of poverty or disgrace--the developed societies were quite beyond that--but for most of the returning experts their careers, status, professional identities, and morale were to require a substantial period of adjustment.

A flamboyant confidence that formerly characterized the giant country, which for decades had been the envy of the developing world, disappeared during the '30s. Still the Brazilian people had attained a relatively high standard of living. The GNP/capita was \$11,000 in 2025 and has during the last 50 years slowly increased to about \$18,000. Their lack of economic dynamism has been replaced by a greater concern for equity, justice, social welfare, and other requirements for a high QOL which had been relatively neglected during the heady growth stage. Thus Brazil is now considered to be a mature post-industrial society without the restless driving ambitions that characterized its "adolescence" during and shortly after the 20th century.

China

During the first quarter of this century the Chinese economic growth rate had started at 6 percent but then slowed to 4 percent (averaging 5 percent). In 2025 their GNP had reached a respectable \$5.4 trillion, or about \$5,000/capita. As they approached this level despite the government planners' efforts to make a harmonious transition into a modern superindustrial society--which earlier had appeared to be feasible--the changes in Chinese society had become so rapid and so complex that their struggle to avoid the pains of successful growth became increasingly frantic. Their need for capital was immense but they remained aloof from borrowing. Their determination to avoid indebtedness, while admirable, had become impractical. They had used up their inexpensive indigenous energy sources and needed to invest about \$5-trillion just to phase into the

long-term inexhaustible sources over the coming decades. Moreover, they avoided buying technology developed abroad and, as usual, insisted on developing their own. This fierce independence was a luxury which was to increase their troubles. Perhaps most important, however, were the emerging QOL issues.

During the preceding quarter the restlessness of the younger Chinese had started to have an increasing influence on their society. Improving communication systems had brought them into indirect but relatively intimate contact with the world's many diverse cultures and the younger people were discovering and expressing a need for more direct interaction. They began to resent the feeling of being constrained within their own relatively severe culture--one bent upon national progress outstanding excellence in performance and cultural greatness, all of which implied a life of dedicated hard work toward conceptual goals that after the early '30s no longer satisfied most of the younger generation. The dissidents' view of the external cultures and especially of the New Class ideology--which to them implied a much improved QOL now, rather than a continued struggle toward hypothetical future gratification--was simply that it was vastly preferable to their own constrained and difficult routines.

The youth "rebellion" received increasing support from many adults who had also become somewhat unsatisfied with their life styles. Television, or even holovision, "travel" generally was not considered an adequate substitute for reality experiences. Listening to music or watching dramas was a poor substitute for performing in these arts. Or more generally the concept of finding and doing your own thing, rather than fitting into the nation's plan, rapidly became an appealing lure, once the new youth subculture became influential.

Naturally the entrenched authorities resisted, but insufficiently; they tended strongly to believe the traditional notion that "it can't happen here" or that the perceived trend would soon reverse itself--while they watched it grow and become dominant. The main part of the struggle, during the period 2030-2050, was generally non-violent; but the outcome was clear before mid-century. The New Class ideology had effectively penetrated the culture, without direct proselytizing, and over the 20-30 year period had won the political battle. With the "fall" of China into the appeal of the foreign cultures there was no longer a nation which could champion the more difficult route emphasizing wisdom and excellence in every important endeavor. Evidently economic success which led to a post-industrial society sooner or later was destined to yield to the temptations of a mode of life with more personal short-term fulfillment. At least this outcome had occurred in nearly every economically successful country in the world. The Chinese culture had been the last real hope for providing to an otherwise stagnant world a dynamic technological and economic model with a far reaching outward-bound vision of human destiny.

During this last quarter (2050-2075) China's economic growth was almost nil after having averaged 2 percent during the previous one. Their recent R&D budgets for science and technology, including space development, have been shrinking. However, at \$10,000 per-capita GNP the population is free of poverty, their health is good, and they devote themselves to work-play or play-work much as in the Western world. Their political wrangling, of course, has been furious as it is almost everywhere, as the government remains under pressure from innumerable factions struggling to improve the elusive QOL for the citizens.

Chinese technologists and scientists have lost their former elevated status but still keep the productive part of society going by developing or maintaining the automated systems upon which the country's material well-being depends. Compared to the conditions of a century ago it appears to be a very good life for most of the people. For those who remember and long for a world of continuing progress, wisdom, and outstanding performance in all fields of endeavor--and, as one of its principal manifestations, for the ascendance of the Chinese people into the farflung reaches of space--for them the current world is a shallow one spinning slowly, endlessly, round and round but with little hope of making their great dreams come true.

The Perpetual Garden

So many forecasts of the future had been made in the late 20th century that almost any outcome would have had at least one prophet. As a post-industrial society develops, the tendency of most people to lose interest in advancing technology and economic growth had long been noticed and frequently discussed. Indeed, it had become one of the primary 20th century images of the future--probably because it had already started to happen in the wealthier nations. Thus, a major surprise-free prediction of that time--reflected in the wealthier nations by New Class ideology--became a kind of self-fulfilling prophecy. But it became even more than that--in the sense that the attraction of the concept also spread to the other countries of the world, once they had developed their economies sufficiently.

Whether or not the actual outcome was inevitable, advanced technology has been used to promote it. Every major accident which occurred during the last quarter of the 20th century and subsequently, and that could help promote the spread of New Class ideology, employed modern advanced communications to bring the details to the attention of the public. Over the course of the next fifty years some special horrors occurred that helped greatly in fostering the influence of this ideology. For example, any trouble with nuclear power plants became instant headline news after 1970. When the first really major accident occurred in 1991 in a "runaway" reactor near Los Angeles that enveloped a substantial portion of that huge city with a radioactive cloud, the ensuing panic as people struggled to rush out of the city only ensnared the flow of traffic, adding automotive exhausts to the troubled city. Unfortunately

the accidental release of radioactivity was also coupled with an atmospheric temperature inversion and other meteorological conditions which prevented an early dissipation of the radioactive cloud. In retrospect the radioactivity was much less of a threat than the panic--but this could not be communicated to the residents in time. As a result a million people were stranded far from their homes in huge traffic jams and, because of shifting winds, often had driven into, rather than away from, the areas of greatest exposure. The subsequent public fury stayed at an intense level for weeks while the grim details were continually flashed to the world by satellite television, in color.

The following year a liquified natural gas tanker ran aground off Cape Cod; the subsequent explosion and fires caused 500 deaths, 15,000 serious injuries and more than \$60 million in property losses. This was followed in "rapid" order, in 1995, first, by the explosion of a chlorine plant in Yokohama, and then a tragedy in space when, after the first placement of a telescope on the moon, the returning spacecraft with three astronauts exploded, a few seconds after launch, killing the occupants. This occurred on the far side of the moon; however, the tragedy was brought into full view by television pictures relayed from the Lunar Orbiter.

The "small" nuclear war of 1997 between Pakistan and India involved "only" three kiloton-size weapons--but 150,000 deaths and a million severe injuries resulted. The prior war between North and South Korea, in 1993, was non-nuclear but longer and almost as grisly, as civilians bore the brunt of the casualties because of indiscriminate attacks on population and industry. At that time advanced space satellites photographed and transmitted these grim events around the world. "Technology" was blamed by the New Class for making possible each major tragedy.

The list goes on at great length. The essence of a 50-year sequence of tragedies is now preserved in the famous 46-hour video program entitled Lest We Forget. This program is a mandatory part of the present education of every child in the post-industrial nations.

There are some "radical" intellectuals who claim that the emphasis on tragic aspects of technology distorts the "true" picture--meaning that the actual and potential benefits are improperly weighed. This argument has not gathered many adherents--except among dedicated technologists--and tends to become weaker over time. The people prefer their lives to be relatively free of the risks of wars, radioactive contamination, explosions in mines and factories, cancerous chemicals, and threats to the fragile envelope of air that must protect us daily--to name but a few of the many dangers from indiscriminate technology, and the lust for ever-increasing personal wealth.

The tendency in the U.S. today, indeed in most of the world, is to resist any potentially dangerous new technology--or the impact of the uncontrolled "Machine," as the technological subculture is popularly

referred to. In the most important sense this is the democratic process. By a vast majority vote the Machine is to be maintained and carefully nurtured, but it must be kept relatively small in numbers and subservient to the desires of society. For the past 50 years at least, the understanding of science and technology, the basis for the Machine, has required fewer and fewer people, although this is not a trend towards zero. Over these years the technological sectors steadily lost status (that is, political influence) as their active population shrank. Although the ownership and control of industry and R&D establishments are largely distributed among the population or within the government, the knowledge required to maintain or improve technology is now concentrated in the small Machine subculture.

Some of our sociologists are concerned about this development since a number of ominous scenarios about the future role of the Machine are thought to be possible, if unlikely. For example, suppose for society's stability the number of people operating the Machine was required to exceed a certain substantial minimum--that is, to prevent the possibility of a relatively sudden collapse of the production and distribution systems. How can it be assured that this critical point is not reached--especially since social power and prestige are generally associated with the other professions such as Law, Politics, Finance, Publicity, Artistic Performance, Sports, and Management? That is, the argument goes, the QOL in society more and more has become dependent on the Machine while, in a social sense, society increasingly disdains or ignores its technological professionals.

The U.S. space program is now dependent upon a mere 10,000 individuals who alone have the technical training to keep it functioning. Tours in space have recently become relatively popular again and a slow growth trend in this activity probably will continue as long as the Machine personnel can maintain it adequately. After formal schooling and apprenticeship, each of these individuals will be required, over time, to complete at least 10 years of additional study and training to remain qualified professionals. During this period they will be expected to help maintain society's "Garden," without, in a spiritual sense, being a part of it. Our sociologists warn us to keep a careful watch to ensure that this separation of society into two subcultures remains sufficiently satisfying to both parts.

A similar situation, of course, exists in all post-industrial nations, and appears to be relatively stable everywhere. Although some sociologists continue to worry about it, most other people are too busy to be much concerned. Indeed, the very long-term outcome may be beyond analysis in any reasonable sense. The general prevailing attitude is that the technologists are content with their robots, lasers, computers, and rockets, and there is no reason why this should change.

However, the division between the technological and non-technological cultures has grown very sharply during this century. It is almost

as if two alien cultures have managed to live under the same government while one of them shrinks slowly over time yet becomes increasingly vital to the other. The majority is not, at least in principle, vital to the minority- except in the sense that they hold the current political and financial controls.

Now that China, Brazil, and many of the other former "Third World" nations have become post-industrial, the remaining fourth of the world's population--principally in South Asia and mid-Africa--that are still in the earlier stages of industrialization are being helped in their upward struggle so they too may become post-industrialized. Actually this process appears to be proceeding steadily and estimates indicate that in the latter part of the next century that outcome may be quite general the world over.

Growth in economic output has been very slow recently, when it occurs at all. Energy and material consumption in the "Garden" countries has been almost flat for the last two decades. The continuing development of automation in industry is about balanced by the growth in government and private services. To some extent the computation of real GNP is somewhat of an art form, as technical changes accumulated over time make it hard to make meaningful comparisons with GNPs of prior decades; at least many leading economists have been making this argument for a long time. However, the important measure to most people in society is their quality of life. Of course this has to be partially subjective, but the general consensus is that it is gradually improving.

Some of the technologists operating the Machine--the space development enthusiasts in the U.S., for example--have expressed frustration at what they believe is an excessive constraint on funds for projects they would prefer. However, society can ill afford to "lose" many of these highly trained people to the pursuit of expensive projects which may have little social benefit, and possibly some important disutilities--especially as each technologist usually has a substantial area of responsibility that must be maintained for the benefit of society in general. The restlessness or frustration among the technologists has been chronic for some time but has not measurably worsened, according to government studies, and therefore is not expected to pose a substantial threat to society's stability. Thus, our society, or our Garden, to use the popular term, appears to have considerable survival potential for the long-term future. The people are busy, generally content with the present arrangement and do not wish to risk their QOL by supporting new developmental activities which have even a small potential for disruption. Why should they? This Garden is theirs. They expect it to last for a very long time--and to be enjoyed by their children's children's children's...children.

CHAPTER VA MODERATE SPACE DEVELOPMENT SCENARIO
PART I: A REVIEW OF SPACE HISTORY FROM 1985A. 1985-2010Social Attitudes Toward Growth

Almost every adult has experienced the feeling that social changes occur very slowly. It happens more often to those who anticipate a particular change and are waiting for it to occur. Thus, during most of the great depression of the 1930s it may have seemed that prosperity would never come again. The energy crisis of the 1970s and early '80s seemed like it might be unending, etc. But the sluggish appearance of change often is an illusion. Since the industrial revolution began over 300 years ago few people from industrialized countries have experienced even a 20 year period without profound social changes occurring. Moreover the pace of such changes appear to have speeded up during the 100 years since the U.S. Bicentennial.

In this sense, shortly after 1974 the developed countries found themselves in the grip of an (a) economic recession, (b) a constant pressure toward inflation, (c) a conflict between rising pressure groups which believed in limiting economic growth and traditional growth-oriented citizens, and (d) an ongoing ideological conflict between centrally-controlled and market-controlled economies. Although in subsequent decades the world was to change radically, some of the above features were to be surprisingly persistent and would lead to rather agonized or agonizing cultures. Consequently, so much effort was to be spent trying to resolve conflicts but with little success--although new areas of conflict had little difficulty in arising--that a sense of becoming trapped in a web of one's own making began to spread and for several decades had a depressing effect upon public morale in most of the advanced countries.

Despite these socio-political difficulties their economic growth did continue at roughly the 3 percent historical rate during the last quarter of the 20th century. This was probably due in large measure to the ongoing "explosion" in science and technology, in which a growing technical effectiveness was occurring even while public attitudes reflected considerable neo-Malthusian, or New Class, orientation about future supplies, and while R&D budgets usually were under perennial stresses. The "explosion" could continue in such circumstances primarily of the expansion of private R&D investments and because the "electronic revolution" permitted scientists and technologists to do more with less money; those adjustments more than compensated for the stiffening opposition to publicly-funded R&D in science and technology.

The U.S. space program was a case in point. Although the U.S. space budget increased in real terms after 1983 the average increase, only slightly more than the GNP growth, generally was not satisfactory from NASA's point of view, and frequently was a source of bitterness to space enthusiasts who longed to see favorite projects funded. Nevertheless, in reviewing space developments over the quarter century the U.S. program achieved some remarkable results (see Table 7).

During this 25-year period it became clear that the world population would soon stabilize and probably would not exceed 10 billion. The most useful technological assist to this expected outcome was a simple procedure for reversible sterilization that could be applied to either sex, and which for women even became insurable at \$10 per year, with a \$100,000 payout for any resulting pregnancy. The two developers of this technique were awarded the Nobel Prize in Medicine for their contribution to the long-term welfare of humanity.

Military Systems in Space

One of the more disheartening trends was the lack of any meaningful progress towards arms control, conflict resolution, or effective international restraints against war. In this respect the disharmony among nations was reflected in armaments expenditures that easily kept pace with GNPs. The U.S. and the U.S.S.R. maintained their arms "race" by developing various measure-countermeasure "games" to ever growing complexity; this included the deployment of several kinds of space weapons aboard maneuverable platforms--weapons employing various forms of "death rays" which could deliver lethal blows against missiles or satellites up to 30,000 miles away. The deployment of these systems soon came to symbolize national power and military prestige although their utility in a real war would be doubtful at best. Nevertheless, other countries had deployed a few of these weapons by 2010--China, Japan, France, and the European Space Force (for the U.K., W. Germany, and the Netherlands). Moreover, by then these space weapons could be bought by almost any nation which was on sufficiently good terms with any of the above Big Six, as they soon became labeled. Brazil was expected to make them the Big Seven soon, and some military experts predicted a proliferation of these systems to at least another dozen countries by the year 2025.

Non-Military Space Programs

Although the non-military U.S. space program was dampened by a relatively slow increase in funding it was assisted by the cooperation and more rapidly increasing space budgets of other industrialized nations. None of these nations had developed an independent reusable STS (Space Transportation System) to compete with the U.S. Instead they chose to cooperate with the U.S. in building the advanced STS. NASA was pleased with this outcome since it reduced the burden of maintaining the new

Table 15HIGHLIGHTS OF U.S. SPACE ACCOMPLISHMENTS, 1985-2010

1. THE EARTH-ORIENTED SATELLITE PROGRAM WAS A REMARKABLE SUCCESS. IT TOOK OVER ESSENTIALLY ALL NAVIGATION, PROVIDED COMMUNICATIONS, MAPPING, EARTHQUAKE AND STORM WARNINGS, CROP AND WATER INVENTORIES; BECAME AN INDISPENSABLE AID TO MINERAL EXPLORATION, AND OFFERED CONSTANTLY IMPROVING WEATHER PREDICTIONS.
2. THE SPACE TRANSPORTATION SYSTEM DEVELOPED THE IMPROVED SHUTTLE AND LATER THE AUTOMATED (UNMANNED) SHUTTLE-DERIVED LAUNCH VEHICLE TOGETHER WITH A COMPLEMENT OF SPACE TUGS AND PLANETARY LANDERS FOR MOON AND MARS MISSIONS. BY 2010 THE COST OF LAUNCHES TO NEAR-EARTH HAD DECREASED TO \$100/LB FOR FREIGHT AND \$250/LB FOR HUMAN PASSENGERS (1975 DOLLARS).
3. THE DEVELOPMENT OF A PROTYPE SPACE INDUSTRY HAD REACHED THE POINT WHERE 28 PRODUCTS HAD BECOME MAJOR COMMERCIAL SUCCESSES AND MANY OTHERS WERE DEPENDENT ONLY UPON COMPLETION OF THE NEWEST TRANSPORTATION SYSTEM. MEANWHILE THE R&D FOR NEW PRODUCTS AND PROCESSES IN SPACE REACHED ABOUT \$900 MILLION ANNUAL U.S. FUNDING (3/4 FROM INDUSTRY) PLUS ROUGHLY EQUAL AMOUNT FROM EUROPE AND JAPAN.
4. THE SPACE SCIENCE AND EXPLORATION PROGRAM PRODUCED A SERIES OF SPECTACULAR DEVELOPMENTS. THE SPACE TELESCOPES AND OTHER RADIATION SENSORS REVOLUTIONIZED ASTRONOMY AND COSMOLOGY. THE TWO MARTIAN ROVERS FOUND EVIDENCE FOR RUDIMENTARY LIFE FORMS ON MARS. THE LUNAR STATION NOT ONLY DISCOVERED WATER BUT VERIFIED THE FEASIBILITY OF MINING FOR USEFUL MINERALS AND WOULD SOON TO BUILD THE FIRST SMALL-SCALE ELECTROMAGNETIC ACCELERATOR.
5. THE FEASIBILITY OF A MANNED GEO STATION WAS ESTABLISHED AS WELL AS THE ROUTINE MAINTENANCE OF COMSATS, LARGE GEO ANTENNAS AND SOLAR POWER SYSTEMS.
6. SPACECRAFT MADE CLOSE-UP OBSERVATIONS OF ASTEROIDS AND COMETS--DEMONSTRATING THE POTENTIAL OF THE ASTEROIDS FOR MINERALS AND OF SOME AS HYDROGEN SOURCES.

system and enabled the group to develop a more comprehensive set of orbital transfer vehicles and lunar landers. The combined budgets of the European and Japanese governments for space programs each increased to over \$3-billion annually by 2010--about a 4-fold increase in 25 years. Although growing more rapidly, each was still less than 1/4 of the NASA's budget. To this it was necessary to add \$2.2 billion from U.S. industries and another \$.9 billion from the private industries of the other OECD nations--mostly for investments in communication systems, space tourism and space industrialization processes.

The U.S.S.R. space program continued to grow at its historical 2-3 percent annual rate, although as usual the allocations between military and peaceful purposes were hard to unravel. It was roughly estimated, however, that in the year 2010 the Soviet expenditures equaled those of all of the OECD countries combined. However, the Soviet space accomplishments, while significant, did not equal those of their competitors, except in the military developments. Their principal reusable launch vehicle, operational in 1995, was capable of sending 110 tons to LEO at costs roughly competitive with the improved Shuttle system. Perhaps because by 1999 they had built more of these launchers than they would need for at least another 10 years little improvement in these costs were to occur for at least a decade.

Perhaps the principal surprise during the period was the growth of the Chinese space program. Although their GNP grew from about \$300 billion to \$800 billion or to about \$900 per capita, they made a proportionately much larger commitment to their space ventures which, from a small beginning, rose to an unanticipated \$5 billion annually. The Chinese surprised the world by deploying in 2008 an automated "freighter" which could deliver a 1/4-million pound payload to orbit at roughly \$150/lb--which was less than the U.S. cost. It became quite clear that the Chinese had maintained a greater respect for space science and technology than had most OECD countries and that they intended to be second to none over the course of the 21st century. Chinese presence at international science conferences had been growing rapidly during the quarter and by its end the number of Chinese scientists attending was seldom exceeded by any nation other than the U.S. Moreover, the quality of their contributions to the conferences was highly regarded. Those contributions correlated strongly with the number of their representatives.

The group of prospering middle-income countries. Brazil, Taiwan, Korea, Argentina, Chile, etc., with a combined year-2000 population of about 1.5 billion generally were much more concerned with economic growth based upon imported technology than with space development. Efforts to develop the internal infrastructure needed to support a modern technological society were succeeding but were not to blossom significantly before 2000--and even then great differences among these nations could be observed in their relative successes.

B. 2010-2035

This quarter was destined to be a strange one for space development. On one hand, a technological capability existed in three major blocs--the OECD nations, the U.S.S.R. and its allies, and China--for impressive advances. On the other hand, a major distrust of motives among these powers led to an increasing diversion of funds into military space systems and a 3-way cold war "paranoia" was to prevail and distort prior plans for commercial space developments.

During this quarter the Chinese chose to orbit many satellites, some of which were (erroneously) believed to contain nuclear weapons. In addition, they deployed ever more sophisticated defensive systems which included observational satellites, maneuvering inspection satellites, and space-based weapon systems ranging from simple explosives to sophisticated laser and particle beam "guns". Of course, they claimed that these were purely defensive measures to insure the viability of the Chinese space installations as well as to deter possible attacks against their installations on the earth's surface. Inevitably, the Soviet Union and the U.S. felt compelled to respond in kind and a reluctant 3-way space arms race was on.

Although each of the chief protagonists had established small lunar stations soon after 2010 and continued to expand them during this quarter, no weapons were based on the lunar surface. Rather a series of unilateral announcements made it clear that each power intended to avoid military installations on the moon except for possible communication and observation systems. This understanding permitted lunar observatories, technical laboratories, and exploration stations to proliferate in accordance with the international space laws that had previously been worked out under U.N. auspices.

The lunar inhabitants understood, however, that if serious disputes arose which required legal resolution by international courts on earth, the viability of all lunar installations would be shaky. Meanwhile, for lunar dwellers the experience of living and working on the moon had a very strong psychological impact. They found it extremely difficult to feel anything other than respect and friendship for their "neighbors" with whom they maintained close communications. The political or military affairs on earth rapidly became as psychologically distant as the "big blue marble" was physically distant. As a result the lunar inhabitants rapidly gravitated toward a common feeling of belonging to a special lunar society which, however "primitive," was in many respects beyond traditional nationalism. The longer one remained on the moon the more did nationalism appear to be a ludicrous basis for organizing human society. (This perspective was to lead eventually to the formation of the United Lunar Authority, the leadership of an international lunar society which in turn was destined to become independent of earth governments.)

The Great Space War

One difficulty with space development during this quarter was related to a growing fear of war and some concern for the manned installations in earth orbit--especially within the fledgling space industries for which there was so much hope. Private investment in expensive new facilities continued at a high level despite the apparent war prone environment. Most people did not believe that a war would actually happen although later, in retrospect it was obvious that the political situation had become so unstable that war was almost inevitable before the quarter ended. Even though it was clear that any new space facilities could very readily be destroyed by weapons which were constantly within view, except for sporadic fears, investments in space continued to climb. It was also true that defense theorists and war planners generally considered the small number of R&D and maintenance personnel in space to be potential "demonstration targets," for any one of the three powers that first wished to flex its military space muscles. Still, there was no reduced emphasis on manned systems or noticeable restraints on private investments in space.

This "space-based powder keg", which was inherently unstable as a deterrent, resulted in the Great Space War of 2029. In principle, this was a war which could be fought by generals and their extensive staffs of officers, scientists, technologists, and various consultants. It could be played like a chess game with little destruction that would be directly visible and with few human lives involved--providing the war did not escalate to a surface exchange of weapons. Perhaps the script could have been written in advance. A space war was more difficult to deter because a "clean" victory was possible, in principle. No power needed deliberately to escalate to even a limited use of highly destructive surface weapons. Yet just that possibility may have made the war inevitable.

How the shooting started may never be known. Too many irreconcilable claims and accusations have been made that were soon beyond investigation. All that is clear is that the Soviet Union and the Chinese not only blamed each other for starting it, but for escalating it by destroying U.S. satellites in an attempt to catalyze U.S. reprisals against the other side. It was all over--the space battle that is--in one day. Almost everything of potential military value in space that could be shot at, was--often more than once just to make sure. The measure-counter-measure game was played out in full. About 98 percent of all the military satellites and 100 percent of the orbiting military stations had been reduced to scrap in orbit. About half of the non-military satellites on earth-oriented missions were also lost. For both the Soviets and Chinese all of their personnel who had been manning space stations and space industries were casualties. Fortunately for the Americans only one manned installation was fired upon. Altogether, less than 300 lives were lost but perhaps \$800 billion worth of equipment (original cost) was destroyed.

The major blessing, however, was that the destructive orgy did not descend to the surface of the earth. Indeed, as very few human beings knew that a great war was happening until it was all over, they were somewhat incredulous when it was first reported by the news media. Even then it took weeks or more for the reality to sink in. A major war without sound and fury which began and ended in a single day? That concept was beyond human experience except for a few prior fictional portrayals with some accidental similarities, but those had never had much impact in any event. On the moon the stunned lunar inhabitants had monitored many of the events, but they had no precedent or guidance for responding to the strange sudden insanity of it all.

The reaction on earth took years to evolve through the steps of what could have been a well-rehearsed play. The accusations, recriminations, investigations, deliberations would rise up, interact, and subside--over and over like waves emerging sporadically from several epicenters of gradually diminishing power. But from the beginning the wisest heads knew what the principal outcome would be. The orgy was over--for good. Space would be returned to peaceful purposes once again. It would take decades before some investors would be sufficiently convinced that the risk would be worthwhile--but for others, as generally happens after wars, peace appeared to be secure and before long investment began to return. The more astute investors reinvested rapidly and benefited greatly. As a result, a few great corporations were to arise and dominate commercial space enterprises. The Great Space War has been the only space war in history. Fortunately, the human casualties were so few.

Technological and Economic Progress

While military institutions were devoting much of their technological capability to space weapons and space defense systems, scientific, exploratory, and industrial uses of space were also pursued by each of the major powers but at a relatively low level. Nevertheless, lunar-based science and technology, asteroid mapping, exploration by unmanned Martian rovers, and soon afterwards the installation of small Martian scientific stations by the Chinese and the Americans were among the highlights of the quarter. Large space colonies were not seriously contemplated although considerable R&D on the life science aspects of self-sufficient, long duration operations in zero or low-gravity spacecraft were steadily pursued and much progress occurred that was to be field tested early in the next quarter.

Meanwhile the developing countries were making reasonable economic and technological progress. Economic growth ranged from 4 to 7 percent annually for the more ambitious countries, and from 2 to 4 percent for the more traditional cultures. The larger nations (Brazil, Mexico, Argentina, India) became more interested in space activities as their technological capabilities expanded and as they saw some potential for its economic applications. Of course, the Great Space War set all such ambitions back for awhile, but they were reemerging as the quarter was ending.

In an important sense the Space War was to become a boon to future space programs for two reasons. First, it was to lead to an effective international treaty that banned deployment of destructive weapons in space. Second, little of the subsequent funds for space development would need to be siphoned into costly military hardware--the debris of the former investment would be orbiting the earth for a long time. During the next quarter most of that debris was collected and placed into special orbiting museums as permanent reminders of that notorious day--and has furnished some of the more fascinating points of interest for subsequent space tours.

C. 2035-2076

Aftermath of the Space War

The treaty restricting all weapons in space to the United Lunar Authority (see below) became effective in 2041, twelve years after the Great War. But its effect was anticipated well before then, as none of the belligerents had moved to replace their prior systems. The public's attitudes--as reflected by the actions of political leaders--had become all too clear. Indeed, the spill-over to other military systems and ideological concepts led to a gradual withering away of the former arsenals. During the last 40 years the perceived need for elaborate forces for offense and defense under the umbrella of various deterrence concepts faded until only relatively rudimentary capabilities now remain--just minimal "light cover" systems which can keep the military R&D establishments active in the event that unanticipated political developments arise that could make renewed strategic military forces desirable once again. Currently, the need for the light cover and even the R&D is being questioned.

The United Lunar Authority

George Lincoln was an unusual genius who became entranced with the idea of the development of space and space colonization as a vital part of the manifest destiny of humanity. At a critical historical moment he found himself in a position to move both men and nations in that direction. It was largely due to him that in the year 2011 the Lunar Treaty was signed in which the U.S., the Soviet Union, China, West Germany, the U.K., France and Japan, as well as (later) many other powers, joined together in a pledge to create a truly international lunar facility which would be available, under reasonable terms, for use by all nations and authorized persons. By 2027 the lunar facility included an observatory with two major telescopes (one of Soviet and one of American design) and many smaller instruments, a scientific laboratory, an exploration and engineering facility, several launching platforms, two electromagnetic accelerators, habitats with facilities for storing supplies to be used by all parties, and so on. Unfortunately, after 2020, as relations among nations began to deteriorate tensions arose which focused considerable attention upon the wartime role of space satellites, ultimately leading

to the Great War of 2029. Fortunately, however, the United Lunar Authority (ULA), which was nominally under the direction and the authorization of a special multi-national organization, was able to preserve its international character.

In the years of its existence before the Great Space War ULA personnel had developed an extraordinary sense of unity and soon felt separated from national considerations. Their attitudes became quite different from the nationalistic ones which characterized most people and groups on earth. It was their sense of detachment from earth-bound politics and the ever-growing bonds of a common lunar culture that led them to develop among themselves a one-for-all and all-for-one attitude. Furthermore, the selection of personnel to be compatible with that lunar culture was strongly affected by George Lincoln. Most Lunarians became infused or imbued, partly by desire and partly by their interdependence in the lunar environment, with Lincoln's sense of mission and "religious" zeal for unity. They soon lost any former sense of identification with the national rivalries on earth (except as these were clearly constructive for the developments in space).

By 2045 the ULA had evolved into a position where it was trusted by all national groups for controlling lunar issues of most concern. Some of these issues were very important to the survival and continuation of both military and non-military operations on the moon. Although a partial separation of selected lunar activities did occur as a result of pressures from earth towards "nationalization" of these activities (that is, physical separation of facilities for separate national purposes), on the whole the attempts of earth authorities to extend this process were effectively resisted. (Before mid-century the earth authorities, to their astonishment, had learned that a genuine international body was operating all the facilities on the moon.)

Societal Changes

Perhaps most important for general world progress and political stability was the elimination of grinding poverty, which up until this century had characterized most of the world's population throughout recorded history. That poverty had also been closely associated with poor health, illiteracy, extreme corruption, callous urban societies, incompetent governments, and repressive authoritarian societies--in deeds, if not always in form. Nearly all of these conditions disappeared during this century. What vestiges remain are very unlikely to survive to the year 2100. Today almost every child is born wanted, and has a guarantee of appropriate nutrition and health care. Moreover, prior genetic screening essentially guarantees that each new arrival will be free of serious mental or physical defects at birth. It is hard to conceive of a plausible scenario leading once again to illiterate subcultures. Also violent crimes have become quite rare, having had a negative growth (averaging -9% annually for the last 40 years). Although

corruption has not been eliminated it has been greatly reduced and does not exist anywhere in any of its former virulent forms.

By former (i.e., late 20th century) standards ours is a far more wealthy and egalitarian world. The average income in the world today is almost 10 times that of a century ago. Perhaps more important is the fact that the former very poor countries have an average per capita income that is at least 40 times that of 1975. Moreover, it is still the poorest countries whose economies are expected to grow most rapidly in the future, an almost inevitable consequence of the societal changes of the last 45 years and an outcome about which there is little disagreement among our experts.

Technological and Economic Progress

When we leave the social and political areas it is possible to characterize the progress in the more technical areas much more quantitatively. Indeed, wherever appropriate theories and initial data exist most problems can now be expressed in a language which computers understand, and one or more solutions usually can be readily generated--or at least the cost of producing a solution can be determined. Thus, to produce ultra-pure diamond fibers, or develop a fusion engine with 92 percent efficiency, or determine the chemical composition of coal to .1 percent accuracy for the top 300 components, or predict next month's precipitation within 2 percent--these are straightforward problems with straightforward solutions. Today it is taken for granted that improving technology characterizes nearly the entire world and that on balance it will lead to surprising and desirable outcomes--helped by the growing fraction of the population engaged in those activities.

Our "colonies" in the different regions of space specialize in the various technologies which make them most valuable. The lunar and asteroid colonies are furnishing materials for space processing industries. The La Grange point colonies build large space structures: habitats, exploration vehicles, propulsion systems, communications networks and electric power systems. Orbiting factories produce thousands of products and components for both earth and space uses. These include satellites, electronic instruments, ultra-pure crystals, computer "chips," cryogenic alloys, medical specialties, metallic hydrogen, space foods, glassy metal foils, foams, whiskers, and so forth. The huge space depots provide refueling and maintenance services for spacecraft as well as facilities for travelers.

Tourism has become one of our most rapidly growing space industries, especially during the last several years when the cost of the minimum (2-day) LEO tour fell to \$15,000. Indeed, there is a shortage of touring facilities which, because of government regulations, are unlikely to be expanded rapidly enough to meet demand for some time to come.

The GWP today is about \$210 trillion; roughly half of that comes from the countries with large commitments to space: the U.S. whose

space program is integrated with those of Japan, Germany, Brazil, France and others; China; and the U.S.S.R. and its eastern European associates. These three countries and their collaborators represent about \$120 trillion of the current GWP. Their respective annual space budgets are roughly \$200 billion, \$400 billion, and \$200 billion. In addition, from the U.S. group about \$400 billion annually comes from private investment--mostly profits from tourism and space industries being plowed back. Thus, about 1 percent of the GWP of the countries actively involved in space development is being allocated for space purposes. This allocation is high by historical standards but is not expected to diminish.

PART II: THE NEXT 100 YEARS (2076-2176)

I have been asked to make some projections about things to come. Naturally any such projection is likely to be wildly wrong especially as every space buff like me holds a relatively optimistic view, at least secretly. A "typical" optimistic view, when carried out over a 100-year period at a "nominal" 6-percent growth rate, gives over 8 doublings, or about a 400-fold increase in overall economic growth! In comparison, over the last 100 years the GSI* experienced only about a 50-fold increase. Moreover, as space development is no longer in its infancy its growth should be slower over the next century. This maturing is fairly evident now because it is difficult for us to project a huge number of new realms to conquer without entering into "science fiction"-type developments to a large extent.

Much of our limitations in space today was reasonably envisioned one hundred years ago by sensible forecasters of that time. We have not exceeded the speed of light nor evolved methods of transporting people to distant planets by "teleportation," whatever that word is supposed to connote. Of course, we have made some progress which could not have been predicted and therefore would astonish scientists who lived 100 years ago--e.g., the focused magnetic monopole array which permits the exchange of momentum between orbiting bodies without any mass expenditures and which has greatly reduced the cost of orbital transfers. But even in the last century scientists were confident that many unpredictable developments would occur in this one.

Undoubtedly, if during the past 100 years the people had been willing to invest more in space science and technology--for example to make it an increasingly-funded field rather than an erratically funded one--its present size and scope could have been vastly greater and the surprises much more numerous and impressive (for an analogy we can compare a potential 400-fold increase from an average 6 percent growth rate with the 50-fold one actually attained--equivalent to an average growth rate of about 4 percent). However, erratic budgets--with all their inefficiencies--have been much more consonant with historical political realities than the smoothly growing ones which planners prefer.

Consequently, to make a realistic, rather than idealistic projection for the forthcoming 100 years, and taking into account the maturation of space exploration and space industries, I would project the growth in space to be 2 or 3 times that of the economic growth on earth. The latter is expected to grow at no more than 1 percent per annum on average, for reasons which our economists and social scientists have explained quite well, and about which there is a general consensus. Thus, barring the unexpected, the GWP should about double over the next century and

*Gross Space Investment (including military expenditures).

the world's annual investment in space might increase to roughly 8 times its present level--or to about \$10 trillion per year.

Taking this number to be reasonable the next task is to project the manner in which space might be exploited and then to ask what kind of specific developments might result. For this purpose let us consider the topics of: travel, industry, subsidized colonies, exploration, and science. Naturally a great amount of overlap exists among these--a fact which I will ignore. Also I will ignore many other relevant facets of expanding space-based services such as weather prediction and control, furnished through government agencies or government-related institutions and that are now not listed as space investments, as well as questions related to private versus public financing which economists consider to be quite important.

I begin with travel and tourism as the most rapidly growing aspect of space. A hundred years from now I believe that essentially everyone on earth will tour space at least once during his lifetime and that about a 1-month tour in cis-lunar space, including about a week on the lunar surface, would be reasonably representative. After the next 100 years the Space Board's projection is that the transportation costs for a typical tour will fall to about \$20,000 and I allow another \$20,000, for other costs. \$40,000 per person and roughly 100 million tourists annually comes to \$4 trillion, or 40 percent of the assumed total annual space expenditures in year 2176.

Of the \$6 trillion balance my consultants and I have agreed that an appropriate division among the four remaining sectors would be industry, 60 percent; subsidized colonies, 20 percent; and exploration and science, each 10 percent. These percentages are unlikely to be in error by a factor of 2 although the \$6 trillion total is a soft number which could easily be wrong by up to a factor of 5, perhaps more.

An annual investment of \$3.6 trillion in space industries would be about 7 percent of the world's annual industrial investment projected for 2176. The projected space investment would be even greater if much of the electric power needs on earth had to come from space-based installations, as many people (in the old days) thought would be necessary. But electric power generated in space is expected to produce instruments, components, and materials in space for use mainly by other space industries (including transport) and for the end products consumed in space by space tourists, technicians colonists, explorers, and scientists. Secondly, space industries will continue to concentrate on products and processes which are useful on earth and which otherwise would be unavailable, or too expensive if made on earth. At present this second category is about 10 times greater than the first; but the first is expected to expand more rapidly as tourism increases and as space colonies becomes increasingly self-sufficient, in the full sense of the term. Thus I foresee a gradual shift in emphasis over time toward production in space for consumption and investment in

space, while the overall demand for space products and services increases substantially more rapidly than does the GWP.

The expenditures on subsidized colonies refer primarily to the costs for establishing and maintaining new colonies in space prior to the time that they become self-sustaining. This outward-bound process is expected to be an unending one as long as space exploration proceeds and the colonization that follows--whether in orbit or on planetary surfaces--is considered desirable. To date we have subsidized such colonies on and around Mars, around Venus, and in the asteroid belt--in addition to those in cis-lunar space and, of course, on the moon's surface, most of which are now self-sustaining. The estimate that twice the cost of the exploration will be required for subsequent colonization subsidies is roughly consistent with the experience of the past 50 years and no important arguments have appeared that challenge this estimate seriously. Of course, our past experience makes the projection only plausible, not "correct".

In addition, the recent experiments with retirement communities suggest that life in space might become a desirable retirement mode for many senior citizens who are not too attached to their routines on earth. At present the estimated costs for retirement in space are relatively high, although not beyond the means of the wealthiest segments of the population. But these costs are expected to fall substantially and possibly come within the means of average retired citizens in perhaps 50 to 75 years--although many analysts are dubious about the accuracy of this projection as it depends upon a considerable extrapolation of past trends. Of course, such colonies might also be subsidized. However, our projected expenditures only assume that some subsidies would be required during their formative stages. Social experiments of this kind may occur over a few decades, and possibly even for more than the full hundred years of this projection. In any event, I have not allowed that potential development, whose cost and/or desirability is quite uncertain, to significantly affect my projected budget for subsidized colonies (20 percent of the total space budget).

I must admit right off that the separation of space exploration and space science, although conceptually easy, soon becomes difficult upon examining the subjects in detail. Some scientists claim it is analogous to splitting an animal in half--that each discipline is so dependent on the other that budgetary separation makes little sense. Perhaps they will forgive my crude "surgery" as I proceed with the artificial splitting for sake of this discussion.

Up until now a large variety of automated probes and instrumented vehicles of various types, which I group together as different kinds of robots, have been sent to inspect every planet in the solar system and their satellites. The information obtained has given us a remarkably improved picture of the solar system and we will continue to get more information from these marvelous robots. The manned orbital explorations

of Mercury, Jupiter, and Saturn which have taken place so far have been pilot projects rather than full-scale scientific assaults on the exploration missions. Of course, Jupiter itself is especially difficult because its intense radiation fields prevent a close approach by humans. But this year the U.S. expects to put the first permanent manned installation on the surface of Mercury as one of its Tricentennial celebrations. Manned surface stations are being planned for the smaller moons of the outer planets: those of Jupiter in 5 years, and of Saturn perhaps 10 years later if the Jupiter mission is successful. The Interplanetary Exploration Society (IPES) believes that within 30 years we will find the first humans (temporarily) on Pluto and, within 50 years, a permanent station on that planet.

However, as the members of IPES agree, the ultimate mission of their organization is an expedition to one of the nearby stars. I believe there is little prospect of launching such an expedition during the next 100 years, however, unless some very unexpected and startling breakthroughs occur which could make such a journey appear feasible. Until now we do not know if even one of the 48 interstellar probes which were launched during this century will reach its destination sufficiently intact to return a message that it has arrived. At least 5 of the first 6 have failed in transit--their messages are overdue and they were all functioning for at least a year after their launchings. However, there seems to be no shortage of predictions and detailed descriptions of potentially successful voyages--or of preliminary designs of interstellar vehicles which might be launched with anywhere from 4 to 10,000 people during this or the next century, depending upon various assumptions about future technological progress.

In a relatively pure sense space science and technology have accomplished an astonishing set of "miracles" during this century--the full appreciation of which has, as usual, been limited to that portion of society which devotes the time required to understand the changes which have occurred. For example, the study of the sun has evolved to the point where scientists can now confidently predict a year or more in advance, with accurate timing, the number and sizes of "sunspots," those great solar flares which in prior decades were a major threat to manned activities because of their potential for sudden unexpected showers of destructive radiation. Now the threat is of minor concern since future flares are routinely predicted--and available at least 6 months in advance--in the Solar Science Data Base. In addition, the "small" fluctuations of the solar constant have been accurately modeled. This is also important because the accuracy of these predictions gives us confidence, not only in the life cycle of the sun, but in our understanding of the interior processes in all stars for which the required basic data is available. Such data is now available for over 100,000 stars of our galaxy.

To observers of planets in distant solar systems astronomical progress has been a source of great satisfaction. The planets which have been counted, weighed, and had their orbits measured, now number over 1500

for the nearest 800 hundred stars. Three of these planets show promising conditions for the existence of life and naturally have become the preferred objectives of some of the interstellar probes.

That the former mystery about the existence of black holes has been cleared up is old news of course. But that their sizes and distribution are now almost completely catalogued for this galaxy is a matter of great scientific importance. With this information in combination with other data, the new cosmology has shown conclusively that a portion of the universe must have existed prior to the Big Bang. To many cosmologists recent this result came as a great surprise. Another scientific conclusion that now appears to be certain is that at least 5 percent of the galaxies are made up of anti-matter. In particular, our nearest galactic neighbor, Andromeda, is one of the anti-matter ones and therefore intrinsically forbids human presence. The theory of formation and preservation of the anti-matter galaxies was one of the vital keys of the new cosmology.

In addition to these space spectaculars other developments of this century--which by now cannot be separated from space science--have led to brilliant technological achievements in the maintenance of human health--in adapting to the space environment as well as to the stresses found on the earth's surface. Thanks in part to this progress, the 20th century (and prior) concepts involving fears of death are now much more than a lingering memory. Death today is almost always a natural, pleasant and usually voluntary experience which occurs when the time is ripe.

A full catalogue of achievements over the last hundred years would take volumes just to record those of greatest importance. In every field of basic science there has been at least one fundamental revolution in understanding. In applied sciences there have been thousands of breakthroughs which have led to weather control, inexpensive energy, pristine environments, supermaterials, and now the era of superrobots--without which there might be little time left for politicking and complaints.

One of the interesting experiences for children today is that of visiting the reconstructed Bicentennial village in which the way of life of our great grandparents is accurately replicated. Children almost always find it astonishing in their first visit. Noisy gasoline engines, vacuum cleaners, pot-holed roads, record players, oil-burning furnaces, incandescent lamps, trash cans, fire stations, and movie theatres are all novel--and to them astonishingly "primitive."

I have been dwelling upon past progress, but what of the future? In pure science we simply cannot even guess; it is the discovery of that which before was not known. However, in applied science or technology we can make some guesses. Here are a few:

Genetics: a complete unraveling and understanding of the life process of human beings. That is, from the DNA sequence a complete

prescription of any stage of the growth process which occurs through sequential cell divisions and specialization.

Materials: The ultimate materials for use in functional design to achieve optimum strength, flexibility, geometry, and corrosion resistance will be achieved in 10,000 or more materials. Also materials superconductive at the maximum temperature which is theoretically possible (260 K) will be created.

Computers: The theoretical limit to operational speed and information transfer, unlimited ultra-high-density memory, reliability greater than that from external "freak" accidents, and automatic programming through simple voice commands will all be achieved.

Robots: Which can do anything mechanical that a man does first and wants the robot to repeat--and more. Intelligent robots will be created that can quickly learn to perform "thinking" tasks in most of the ways in which humans can--but much more rapidly.

Space development: Large colonies (with 5000 to 100,000 people) will be able to travel anywhere in the solar system and will be self-sufficient for at least 20 years, perhaps indefinitely. Cost of space transportation will fall by a factor of 10 or more. At least 100 million people will have "permanent" homes in space colonies.

One of the socio-political consequences of the above developments is that human beings in space colonies, whether in orbit or on a planetary surface such as the moon or Mars, probably will become politically independent of societies on earth--that is, they will become "sovereign" in the same sense that nations on earth are. Most sociologists today believe that this is an inevitable result in space--just as it has been on earth. I can only assume that those natives will be friendly--if we are.

Chapter VI

CONCLUSIONS

One of the purposes of this report is to assess the likelihood of favorable long-term developments in space and contrast them to the likelihood of relatively unfavorable ones. For that task the study first establishes a long-term basic context--or surprise-free earth-centered context. The importance of context should be quite clear. Unless the environment from which the space program is to emerge inherently permits optimistic developments then there can be none. While this is an obvious point it is more important than it might at first seem. That is because a relatively large (and up to recently, growing) group of people have emerged in the industrialized nations during the last 15-20 years who have become convinced that the earth's physical resources are inadequate to sustain even modest rates of economic growth let alone a significant expansion of recent growth. The nature of and values of this group, or these groups, is described in Appendix A.

However, research by the Hudson Institute, and others, since the early and mid-1970s has led to the conclusion that any limits to future growth in the world are unlikely to be set by shortages of physical resources. Legitimate concerns about the prospects for long-term growth should rather be focussed upon various ways in which productivity might be constrained by changing social values, management styles or competence of governments. Of course, other developments made possible by unexpected technical breakthroughs or even sheer "luck" might also affect the rates of economic growth.

Consequently, it is appropriate to assume that if there are any future constraints on space ventures they will not be meaningfully related to any limits in the amounts of the earth's physical resources. Accepting that conclusion, the discussion in the latter half of Chapter II shows that the long-term potential for successful developments in space depend upon a number of less-tangible factors, a few of which are reviewed below for their implications about successful space futures.

Technology

From a review of the technological prospects in various fields it is difficult to avoid the conclusion that future technological progress is likely to continue to be rapid until it is constrained by political or social factors. Technical or economic difficulties are unlikely to limit this progress significantly. Indeed, there are good grounds to support the claim that technological progress in the years ahead, however it might reasonably be measured, is likely to proceed faster than it has during the last few decades. This is an exceedingly important trend, which stems from technological changes which are able to focus innovation ever more strongly upon what is popularly by known as high

tech. In the outlook for space development that is exactly what is needed to support the technical aspects of space ventures.

Although it is reasonable to assume that technology will progress quite rapidly in the future, for a space advocate it would also be desirable if a certain amount of technological "luck" occurred. An example would be the unexpectedly rapid development of efficient launch vehicles which would enable transportation costs from the earth's surface to LEO to drop rapidly. A second desirable area of progress, one which will be required eventually, is a practical solution to closed-cycle agriculture within space stations, space vehicles or Lunar colonies.

Still another area in which technological problems will eventually be relatively crucial is that related to the health aspects of prolonged travel in space. The primary concern in this regard are the potential problems which might be associated with months or years spent in a micro-gravity environment. Problems of these and other types will be intensively examined for many years to come. There appears to be a relatively good likelihood that adequate solutions will be found for them within a reasonable time. However, it is obvious that finding those solutions at low cost or relatively early in time cannot be counted on. They are intrinsic imponderables that only time and effort will resolve and for which "luck" becomes quite important.

Another class of future events which may either enhance or degrade the reliability of space ventures are related to their economics. As we know, while the space environment has many resources which can provide important advantages (see Chapter II) nevertheless it also has certain intrinsic costs or disadvantages. Also important to the future of commercial space ventures will be the need to compete with new earth-bound technologies. For example, in recent years the tremendous potential of COMSATS has been seriously affected by the commercial development of glass fibers for telecommunications. That development does not completely offset the future need for COMSATS but it will have a considerable effect upon their rate of expansion over the long-term. In particular, there appears to be four areas in which economic success can contribute to the growth of commercial space ventures. These are (a) COMSATS (b) ERSATS (Earth Resource Satellites) (c) space travel and tourism, and (d) space industrialization, which is now just barely into the required R&D. Space industrialization is in the embryonic stage. Various prognostications for its future range from mildly interesting to extraordinarily successful. At this time its future over the next 50 to 100 years must be regarded as essentially opaque.

However, one of the more likely success stories for commerce in space is expected to come from travel and tourism. The likelihood that costs will decline over time, coupled with a growing worldwide affluence, constitutes a natural combination of circumstances that will favor the growth of space travel and space tourism. The projections

given in this report indicate that even in relatively pessimistic scenarios space travel will be a major long-term growth industry which in turn should contribute to the development of other space ventures.

Of course other economic aspects of space may be determined by bits of luck. For example, whether or not water exists on the moon in reasonable quantities, permitting it in principle to be mined for use by lunar colonies is, from a long term point of view, a very important matter. Without getting into technological details it is clear that the availability of water in particular, or of a local source of hydrogen, more generally, would be a vital element for both human consumption and many lunar industrial processes. The need to provide water and/or hydrogen from the earth could severely limit the creation or expansion of colonies on the moon and other planetary bodies, as well as orbiting colonies in space.

Social and Societal Considerations

In these areas, not only for analysis of space futures but for the analysis of social and political futures of almost any region on earth, there are intrinsic difficulties in making accurate forecasts. It seems, therefore, more useful simply to state that scenarios which envisage not only scientific, technological and economic uses of space but also an expanding extraterrestrial population occupying preferred regions of space on behalf of their nations, of the international community, or on behalf of themselves, must assume the existence of enthusiastic support from special interest groups and/or national governments. During past decades, and very likely for the near-term future, the primary support for space ventures has come from the resources of national governments. Consequently the attitudes of those governments--presumably reflecting the desires of the people of their respective countries--are and will be crucial.

In the developed nations a growing interest in space exploration and commercial development has appeared in recent years. As technology makes space relatively more accessible and lowers the cost of space ventures, governmental interest in its utilitarian services as well as in some of the existing possibilities related to space colonies and manned exploration of the outer planets should continue to grow. Whether the recent growth of public interest in space ventures is a passing fad is open to conjecture. It is tempting, however, to conclude that it will be a relatively permanent trend, at least as long as great disasters in space are avoided and a stream of space "spectaculars" continues to flow into view as in the past.

A second aspect to the social or societal considerations is related to the development of an acceptable minimum of space cooperation among nations, several aspects of which are discussed in Chapter II. There is considerable evidence that the growing interest in space among nations

coupled with the relatively large costs of some space ventures (large launch vehicles, space stations, colonies, etc.) tend to induce greater levels of cooperation among, at least, relatively friendly countries. Even the U.S. and the U.S.S.R. have been more or less cooperative in selected aspects of space exploration, and they appear likely to continue at least that mild level of cooperation for years or decades to come. It is also possible that the mild cooperation could, over time, change into relatively close and extensive cooperation. If that occurs it could give a major boost to projects such as a large lunar colony or a space station on Mars.

Finally, one of the important long range considerations, if colonies in orbit or on planetary surfaces are to become feasible, is related to a larger issue which might be termed the quality-of-life in these colonies. In this matter it is difficult to justify high confidence in the outcome as it requires visualizing, or attempting to visualize, practical solutions to complex social problems which might not occur for several decades or more. Of course the early problems associated with life in "colonies" are likely to be those connected with L.E.O. space stations in which only a few to several people are in residence at any time. Later during this century or early in the next one similar problems are likely to be faced by the residents in lunar bases which may be occupied by only a few or perhaps several people. Then after a longer period of time, say 40 to 50 years from now, these space stations may have been expanded to accommodate several hundred people, or more. Each situation must be expected to pose the usual problems of a social organization, as well as the unusual ones related to living with people in relatively close quarters in a novel environment remote from home and traditions. Even the comfort of knowing that the principal social problems would occur during the early years of such colonization cannot be given with assurance.

While some of the aspects of life in space colonies are dealt with in our scenarios, and have also been examined in papers and scenarios by other writers, it is quite beyond any reasonable conjecture at this time to expect to establish an overall perspective on the social dynamics in space which can be termed reliable. Certainly in this respect the possible range of outcomes gives rein to both optimistic and pessimistic preferences. Only the real future is apt to be of much use in deciding among them.

In all of our scenarios, social values become a dominant force which determines a relatively pessimistic or optimistic outcome. In particular, it is important to see these outcomes as reactions of populations to

* See, for example, Living on the Moon--an article by Philip Harris based on sociological research by B.J. Bluth and others; The Futurist, April 1985.

growing affluence. While there are many ways in which growing affluence could cause values to change, the scenarios emphasize two major possibilities.

In the Pessimistic Scenario, increasing affluence primarily is used to (a) solve the problems of poverty (b) reduce risk to health and safety and (c) provide relatively egalitarian societies that become more and more averse to technological and economic progress because these involve risks which are unacceptable. As a result, concepts of rapid progress, glory, exploring new worlds, ultimate destiny, etc., become potential threats, much as the 18th century landed aristocracy in Europe may have seen threats in the industrial revolution.

The Optimistic Scenario emerges from a completely different perspective. It represents an insatiable desire for and confidence in the ability of humans and their institutions to solve both technological and social problems and to phase into a new era in which freedom from poverty and insecurity releases a cornucopia of creativity, enhanced by cooperation. Thus it postulates that mankind's future no longer need be driven by the fears of poverty and insecurity. Rather, that during the coming decades a flood of economic and technological progress, coupled with common sense, enables new kinds of humanism and humanitarianism to spread rapidly throughout most societies. The lust for personal power and wealth become transcended as societies find that their common goals can better be obtained through striving for excellence and wisdom based upon education, progress, and the wealth which these make possible. Over time, each person becomes much more productive, and the available number of trained well-educated people become far greater than at present. Consequently, the world's per capita income expands rapidly.

Space development worldwide, even in pessimistic scenarios can become impressive over a century and astonishing over two centuries. This can be understood in an economic sense by observing that space investments reach 10 to 50 times the current levels and that a given investment buys much more in the future as a result of ongoing progress. Still, in the Pessimistic Scenarios the world is similar to the present one.

In the Optimistic Scenario, rapid progress occurs in every field subject to change, especially in education, science and applied technology. Also it results in effective approaches to interpersonal and intercultural relations. In that scenario the space frontier becomes a major symbol of human destiny which in turn becomes identified with increasing knowledge of and the desire for more direct experiences with the entire universe--beginning of course with the solar system.

Each scenario in this study ends successfully. However the nature and degree of the success and the paths followed over a 100 to 200 year period are enormously different. Eventually, perhaps even the Pessimistic Scenario could reach an outcome similar to that of the

200-year Optimistic Scenario. But it would require major changes in cultural values and then another century or two to make up for lost time.

Obviously, also, many other scenarios are possible. Indeed, in especially tragic ones, human life on earth could be destroyed, more or less completely, along with many other animal and plant species. Such scenarios cannot be ruled out of the range of possible futures, but they are outside the scope of this project.

It is also important to point out that while history may be one of our best guides for the short-term future, it may also be largely irrelevant for the long term future in space. In Appendix B, for example, a perspective on space futures is developed based upon historical parallels. While illuminating, this history also tends to reflect the prior long term intra and intercultural struggles which were largely based upon the age-old search for power and wealth. Can mankind progress beyond such endless struggles which are reminiscent of our jungle heritage? If so, what new perspective replaces the historical ones? Both the Pessimistic and Optimistic Scenarios provide answers--quite different ones--to these questions.

To sum up, the long term future in space looks exceedingly bright even in relatively pessimistic scenarios. The principal driving forces will be technological progress, commercial and public-oriented satellites, space industrialization, space travel and tourism, and eventually space colonization. The rate of these developments are to be determined partly by luck but mostly by social and political dynamics which are largely imponderable.

LIST OF ACRONYMS

CCD: charge-coupled device
 COMSAT: Communications Satellite

 EFF: efficiency
 E-M: electro-magnetic
 ERTS: Earth Resources Technology Satellite
 ESA: European Space Agency

 G: gravity
 GHZ: gigahertz
 GNP: Gross National Product
 GSI: Gross Space Investment
 GSO: geosynchronous orbit
 GSP: Gross Space Product
 GWP: Gross World Product

 HEAO: High Energy Astronomical Observatory
 HLLV: Heavy Lift Launch Vehicle
 HYV: high-yield variety

 INTELSAT: International Telecommunications Satellite Organization Society System

 K.E.V.: thousand electron volts

 LANDSAT: Land Satellite
 LEO: low-earth orbit

 MBPD: million barrels per day
 MISS: Made In a Space Station
 MPD: magnetoplasmodynamic

 NASA: National Aeronautics and Space Administration
 NATO: North Atlantic Treaty Organization
 NIMBUS: NASA Improved Meteorological Satellite

 OECD: Organization for Economic Cooperation and Development
 OFS: Outlook for Space
 OPEC: Organization of Petroleum Exporting Countries
 OTV: Orbital Transfer Vehicles

 QOL: quality of life

 SEASAT: Sea Observation Satellite
 SEP: solar electric power
 SEPS: Solar Electric Power System
 SI: Space Industrialization
 SMM: Solar Maximum Mission
 SSPS: Solar Satellite Power System
 SSTO: Single State To Orbit
 SSUS: Spinning Solid Upper Stage
 STS: Space Transportation System

 TIROS: Television Infrared Observation Satellite
 ULA: United Lunar Authority
 VTOL: Vertical Take Off and Vertical Landing

BIBLIOGRAPHY

- Bekey, I., Mayer, H.L. and Wolfe, M.G. Advanced Space System Concepts and their Orbital Support Needs (1980-2000). Volume I: Executive Summary. ART-(7365)-1, Vol. I. Volume III: Detailed Data - Part I: Catalog of Initiatives, functional Options, and Future Environments and Goals, ATR-76 (7365)-1, Vol. III. El Segundo, California: The Aerospace Corporation, April 1976. Corporation, April 1976.
- Bell, Daniel. The Coming of Post-industrial Society; A Venture in Social Forecasting. New York: Basic Books, 1973.
- Braudel, F. Capitalism and Material Life: 1400-1800. New York, 1973.
- Braudel, F. The Mediterranean and the Mediterranean World in the Age of Philip II (New York, 1972).
- Brobst, Donald A. and Pratt, Walden P., eds. United States Mineral Resources. U.S. Geological Survey Professional Paper 820. Washington, D.C.: U.S. Government Printing Office, 1973.
- Harris, Philip Living on the Moon. Based on sociological research by B J. Bluth and others; the Futurist.
- Hawkes. J. Prehistory and the Beginning of Civilization. New York, 1963.
- Kahn, Herman. "On Studying the Future." In Handbook of Political Science. Volume 7: Strategies of Inquiry, pp. 405-442. Edited by Fred I. Greenstein and Nelson W. Tsby. Reading, Massachusetts: Addison-Wesley Publishing Company, 1975.
- Kahn, Herman and Brown, William M., et al. The Next 200 Years in Space (NASA Bicentennial Planning). HI-2352-RR. Croton-on-Hudson, N.Y.: Hudson Institute, October 23, 1975.
- Kahn, Herman, Brown, William and Martel, Leon. The Next 200 Years: A Scenario for America and the World. New York: William Morrow and Company, Inc, 1976.
- Kahn, Herman, Brown, William. Long-Term Prospects for Developments in Space (A Scenario Approach). HI-2638-RR. Croton-on-Hudson, N.Y.: Hudson Institute, October 30, 1977.
- Kahn, Herman, The Alternative World Futures Approach. HI-787-RR. 21 November 1966.
- Kahn, Herman., Weiner, Anthony. The Year 2000. New York: 1967, p.7.

- Kahn, Herman., Bruce-Briggs. Things to Come. New York: 1972, pp. 8-9.
- Lavender, David. Bent's Fort. Garden City, N.Y., 1954.
- Marx, Leo. The Machine in the Garden: Technology and the Pastoral Ideal in America. New York: Oxford University Press, 1964.
- Morison, S.E. The European Discovery of America. Boston, 1971 & 74.
- Morison, S.E. Admiral of the Ocean Sea. Boston, 1942.
- National Academy of Sciences. Practical Applications of Space Systems. 1974 Summer Study. Washington, D.C., 1975.
- National Aeronautics and Space Administration. A Forecast of Space Technology, 1980-2000. SP-387. Washington, D.C.: Scientific and Technical Information Office, January 1976.
- _____. Lunar Utilization. Abstracts of Papers Presented at a Special Session of the Seventh Annual Lunar Science Conference, 16 March 1976. Sponsored by the National Aeronautics and Space Administration. Houston, Texas: Lunar Science Institute, 1976.
- _____. Proceedings, Third Space Processing Symposium: Skylab Results. April 30-May 1, 1974. Marshall Space Flight Center, Alabama.
- _____. The Proceedings of the Skylab Life Sciences Symposium. August 27-29, 1974. Houston, Texas: Johnson Space Center, November 1974.
- Office of Technology Assessment. Civilian Space Policy and Applications, STI-177, Washington, D.C., June 1982.
- O'Neill, Gerard K. The High Frontier: Human Colonies in Space. New York: William Morrow and Company, Inc., 1977.
- _____. Outlook for Space. SP-386. Washington, D.C.: Scientific and Technical Information Office, January 1976.
- Parry, J.H. The Age of Reconnaissance (New York, 1964). Atlantic.
- Ridpath, Ian. Worlds Beyond: A Report on the Search for Life in Space. New York: Harper & Row, 1976.
- Skinner, B.F. Beyond Freedom and Dignity. New York: Alfred A. Knopf, Inc., 1971.
- Rockwell International, Space Division. Space Industrialization. Final, Part I: Technical Report. SD 77-AP-0076. Rockwell International, July 15, 1977.

Rowse, A.L. The Expansion of Elizabethan England (New York, 1955).

Stine, G. Harry. The Third Industrial Revolution. New York: B.P. Putnam & Sons, 1975.

The Wall Street Journal. "Business and 'The New Class'." 19 May 1975, p. 8.

Toynbee, A.J. A Study in History London, 1934-1961.

Turner, F.J. The Frontier in American History. New York, 1920.

U.S. Congress. House. Committee on Science and Technology. Future Space Programs 1975. A Compilation of Papers prepared for the Sub-committee on Space Science and Applications. 94th Cong., 1st Sess., September 1975. Committee Print, 2.

von Puttkamer, Jesco. "Developing Space Occupancy: Perspectives on NASA Future Space Programme Planning." Journal of the British Inter-planetary Society 29 (1976).

. Walden Two. New York: The Macmillan Company, 1948; reprint ed.. New York: Macmillan Paperbacks, 1962.

Appendix A*

THE NEW CLASS

Many futurologists and others who speculate about social trends have long recognized that for a wealthy country the marginal utility of successive increments of wealth could decrease quite rapidly. Thus the idea has been widely accepted that sometime within the next hundred years the desire for increased wealth could decrease to the point where it would strongly affect economic growth rates. However, prior to the late 1960s almost nobody expected this effect to be felt in the near future, although many now believe that it is well underway. In particular, it has shown up in changed attitudes which strongly support a set of New Emphases which are listed below:

RECENT NEW EMPHASES (ALL LEADING TO "SOCIAL LIMITS TO GROWTH")

1. RISK AVERSION
2. LOCALISM
3. COMFORT, SAFETY, LEISURE AND HEALTH
4. PROTECTION OF ENVIRONMENT AND ECOLOGY
5. LOSS OF NERVE, WILL, OPTIMISM, CONFIDENCE, AND MORALE
6. PUBLIC WELFARE AND SOCIAL JUSTICE (INCLUDING EQUALITY OF RESULT)
7. HAPPINESS AND HEDONISM
8. GENERAL ANTI-TECHNOLOGY, ANTI-ECONOMIC DEVELOPMENT, ANTI-MIDDLE-CLASS ATTITUDES (E.G., "SMALL IS BETTER" AND "LIMITS-TO-GROWTH" MOVEMENTS)
9. MANY MODERN FAMILY VALUES
10. GENERAL DE-EMPHASIS OF (OR EVEN HOSTILITY TO) THE THIRTEEN TRADITIONAL LEVERS
11. INCREASING SOCIAL CONTROL AND "OVERALL PLANNING" OF THE ECONOMY OF THE "WRONG" SORT
12. ADVERSARY REGULATORY ATTITUDES
13. INNER SPACE (OMPHALOSKEPSIS) AND/OR CONCERN WITH SELF GENERALLY, PERHAPS EVEN AN EMPHASIS ON MYSTIC OR TRANSCENDENTAL VALUES

*This Appendix draws on previously published material by B. Bruce-Briggs and Herman Kahn.

If a new ideology represented by the values given in this list should become pervasive, it could effectively impede advancing technology in general and space development in particular. Therefore, it is worth discussing some of the forces that give rise to the above New Emphases.

First, and perhaps most important, as the membership of the upper-middle class increases, and as the availability of cheap and inexpensive services decreases, the upper-middle class gradually discovers that its pleasures, privileges and purposes, as well as its quality of life and even its standard of living, became more and more threatened. Recent books have discussed these social phenomena in some detail, although often from a somewhat confused perspective. That is, the issue is usually discussed as if the perspective and interests of the upper-middle class were the same as those of average citizens. Little recognition is given to the fact that a middle-class individual who moves into the upper-middle class generally feels a substantial improvement in his standard of living and his quality of life, even if those already in the upper-middle class feel they have lost something.

Within the upper-middle class resides an active sub-group which seems to constitute--intellectually, politically, and polemically--a cutting edge of this phenomenon and which has been labeled the New Class. These are people whose status and occupation not only derive from possession of considerable education, but who earn their living thereby--i.e., by the use of language and analytical skills. The New Class encompasses a large part of academia, the media, most "public interest" groups, and many philanthropic, public service, and social service organizations--all of which not only have grown in size since 1970 but gained considerable influence and power in the industrial Western countries and in Japan. While there are probably many "gray areas" in these categories, that has also been true of previously recognized classes. It is equally difficult to delineate "aristocracy," "bourgeoisie," and "proletariat" with great precision; each of these classes contains important sub-classes as well as a flux of new arrivals and dropouts.

Initial analysis suggests that the New Class can be defined in terms of (a) relatively large or potentially large amount of formal education, including students, (b) professional status in occupations with an emphasis on the "soft" sciences and arts, (c) high (but not the highest) income, usually from non-market sources (government or non-profit salaries, grants, and contracts), and (d) relative youthfulness. The last is important; because the New Class has been "emerging" its attributes should be most obvious among the young. In this connection, Karl Marx's insight that a class does not exist unless it has self-awareness is illuminating. This kind of consciousness has appeared only recently among members of the New Class. Some intellectuals and bureaucrats have always behaved like the New Class, but perhaps only within the past decade have their numbers been sufficient to achieve the critical mass required to break out of subordination to other groups and establish their own identity.

A case can be made that the New Class largely controls or dominates the following groups and institutions: (a) the humanities and social science faculties of almost all prestige and many state universities, professional schools, and teachers colleges; (b) most of the national media organizations--the prestigious daily newspapers, much of the periodical press, the book publishing industry, the commercial television networks, recording, films, and most educational media; (c) the fine arts; (d) the establishment foundations and other non-profit eleemosynary institutions concerned with influencing public opinion; (e) research organizations; (f) a good part of congressional staff; (g) the federal social welfare bureaucracy; and (h) the government regulatory apparatus.

Furthermore, New Class values and sensibilities have successfully penetrated: natural science faculties; business schools; rank and file school teachers; state and local government bureaucracies; the clergy; advertising; trade union staffs; salaried professionals of many kinds; and even parts of business corporations, especially in public relations, long-range planning, and internal education programs. These disparate groups have the following characteristics in common: they are in staff (as contrasted to "line" or substantive) positions, and they produce or deal in ideas or words, holding their jobs because of analytical and literary skills usually obtained through formal education. Thus the chief executive officers of these organizations generally would not belong to the New Class.

Many analysts concerned with the future of the advanced nations believe that these "brain workers" could become even more important in the next century and play central roles in influencing the general milieu in which space projects will be undertaken. A series of more or less self-explanatory charts are included to give the interested reader a synoptic overview of the characteristics and issues currently associated with the New Class.

ISSUES

- A. ORIGINS OF PRIVILEGED RADICALISM
ADVERSARY CULTURE
LIBERAL ETHOS
- B. CONCERN WITH COMPETENCE OF SOCIETY, ECONOMY, AND
GOVERNMENT
- C. WIDESPREAD BELIEF THAT BRAIN WORKERS WILL BE
DOMINANT CLASS OF FUTURE

BACKGROUND OF THE IDEA OF THE NEW CLASS

- 1. NEED TO DEFINE AND EXPLAIN GROUPS WITH "POWER WITHOUT
PROPERTY"
- 2. TERM "NEW CLASS" EMPLOYED IN 1956 BY MILOVAN DJILAS
TO LABEL COMMUNIST RULERS
- 3. TERM FIRST APPLIED TO U.S. BY DAVID T. BAZELON IN 1967
- 4. TERM USED IN "RIGHT" SENSE BY D.P. MOYNIHAN AND NORMAN
PODHORETZ IN 1972. CIRCULATED BY IRVING KRISTOL.

TWO DEFINITIONS OF THE NEW CLASS

"LEFT"

INCLUDES ALMOST ALL RESPONSIBLE
WHITE COLLAR WORKERS, INCLUDING
ENGINEERS AND CORPORATE
MANAGERS.

"RIGHT"

EXCLUDES "LINE" OFFICIALS
AND PRACTICAL BRAIN WORKERS
AND INCLUDES PUBLIC SECTOR
ENTREPRENEURS

Business and 'The New Class'

By IRVING KRISTOL

Everyone wants to be loved, and it always comes as a shock to discover that there are people who dislike you for what you really are rather than for what they mistakenly think you are. Indeed, most of us desperately resist such a conclusion. We keep insisting, to ourselves and others, that those people out there who are saying nasty things about us are merely ill-informed, or misguided, or have been seduced by mischievous propaganda on the part of a handful of irredeemably perverse spirits. And we remain confident, in our heart of hearts, that if they only understood us better, they would certainly dislike us less.

In this respect businessmen are no human—and are as capable of self-deception—as anyone else. On any single day, all over the country, there are gatherings of corporate executives in which bewilderment and vexation is expressed at the climate of hostility toward business to be found in Washington, or in the media, or in academia—or even, incredibly, among their own children. And, quickly enough, the idea is born that something ought to be done to create a better understanding (and, of course, appreciation) of "the free enterprise system." A television series on economics and business for the high schools? Space advertising in the print media? Face-to-face encounters between businessman and college students? Long and serious luncheons with the editors of major newspapers and newsmagazines? In the end, many of these ideas come to fruition, at substantial costs in money and time—but with depressingly small effect.

Now, I do not wish to seem to be underestimating the degree of ignorance about business and economics which does in fact exist in the United States today. It is indeed amazing that, in a society in which business plays so crucial a role, so many people come to understand so little about it—and, at the same time, to know so much about it which isn't so. We have, for instance, managed to produce a generation of young people which, for all the education lavished on it, knows less about the world of work—even the world of their fathers' work—than any previous generation in American history. They fantasize easily, disregard common observation, appear to be radically deficient in that faculty we call common sense.

A Preference for Fantasy

Nor, it must be said, are their teachers in a much better condition. The average college professor of history, sociology, literature, political science, sometimes even economics, is just as inclined to prefer fantasy over reality. On every college campus one can hear it said casually by faculty members that the drug companies are busy suppressing cures for cancer or arthritis or whatever; or that multinational corporations "really" make or unmake American foreign policy; or that "big business" actually welcomes a depression because it creates a "reserve army of the unemployed" from which it can recruit more docile workers.

So there is certainly room for all kinds of educational endeavors on the part of the business community, and I do not wish to be interpreted as in any way discouraging them. The fact that they seem so relatively ineffectual is not necessarily an argument against them. Education is at best a slow and tedious process, and that kind of education which tries to counteract a massive, original miseducation is even slower and more tedious. Too many businessmen confuse education with advertising, and almost unconsciously impose the short time-horizon of the latter on the former. The unit of time appropriate to the process of education is not a year but a generation.

Having said this, however, I should like to pursue the truly interesting question of why so many intelligent people manage to entertain so many absurd ideas about economics in general and business in particular. In truth, one can properly put that question in a much stronger form: Why do so many intelligent people seem determined to hold those ideas and to resist any correction of them? Such determination there must be, because mere error and ignorance are not of themselves so obdurate. When they are, it is usually because they also are an integral part of an ideology which serves some deeper passion or interest.

And the more attentively one studies the problem, the clearer it becomes that what is commonly called a "bias" or an "animus" against business is really a by-product of a larger purposiveness. There are people "out there" who find it convenient to believe the worst about business because they have certain adverse intentions toward the business community to begin with. They dislike business for what it is, not for what they mistakenly think it

Board of Contributors

There are people "out there" who find it convenient to believe the worst about business because they have certain adverse intentions toward the business community to begin with. They dislike business for what it is, not for what they mistakenly think it is.

is. These people constitute what one may simply call, for lack of a better name, "the new class."

This "new class" is not easily defined but may be vaguely described. It consists of a goodly proportion of those college-educated people whose skills and vocations proliferate in a "post-industrial society" (to use Daniel Bell's convenient term). We are talking about scientists, teachers and educational administrators, journalists and others in the communications industries, psychologists, social workers, those lawyers and doctors who make their careers in the expanding public sector, city planners, the staffs of the larger foundations, the upper levels of the government bureaucracy, etc. It is, by now, a quite numerous class; it is an indispensable class for our kind of society; it is a disproportionately powerful class; it is also an ambitious and frustrated class.

Kevin Phillips calls this class "the mediocrity," in his new book of that title. Though the book has many shrewd observations, the term he chooses seems to me to be unfortunate. It helps prolong what might be called the "Agnew illusion"—i.e., that much of our troubles derive from the fact that a small and self-selected group, whose opinions are unrepresentative of the American people, have usurped control of our media and use their strategic positions to launch an assault on our traditions and institutions. Such a populist perspective is misleading and ultimately self-defeating. Members of the new class do not "control" the media; they are the media—just as

CRC
OF POOR QUALITY

they are our educational system, our public health and welfare systems, and much else. Even if the president of CBS or the publisher of Time were to decide tomorrow that George Wallace would be the Ideal President, it would have practically no effect on what is broadcast or published. These executives have as much control over "their" bureaucracies as the Secretary of HEW has over his, or as the average college president has over his faculty.

What does this "new class" want and why should it be so hostile to the business community? Well, one should understand that the members of this class are "idealists," in the 1960s sense of that term—i.e., they are not much interested in money, but are keenly interested in power. Power for what? Well, the power to shape our civilization—a power which, in a capitalist system, is supposed to reside in the free market. The "new class" wants to see much of this power redistributed to government, where they will then have a major say in how it is exercised.

From the very beginnings of capitalism, there has always existed a small group of men and women who disapproved of the pervasive influence of the free market on the civilization in which we live. One used to call this group "the Intellectuals," and they are the ancestors of our own "new class," very few of whom are intellectuals but all of whom inherit the attitudes toward capitalism that have flourished among intellectuals for more than a century-and-a-half. This attitude may accurately be called "elitist"—though people who are convinced they incarnate "the public interest," as distinct from all the private interests of a free society, are not likely to think of themselves in such a way. It is basically suspicious of, and hostile to, the market precisely because the market is so vulgarly democratic—one dollar, one vote. A civilization shaped by market transactions is a civilization responsive to the common appetites, preferences, and aspirations of common people. The "new class"—intelligent, educated, energetic—has little respect for such a commonplace civilization. It wishes to see its "ideals" more effectual than the market is likely to permit them to be. And so it tries always to supersede economics by politics—an activity in which it is most competent, since it has the talents and the implicit authority to shape public opinion on all larger issues.

Its Own Gravedigger?

So there is a sense in which capitalism may yet turn out to be its own gravedigger, since it is capitalism that creates this "new class"—through economic growth, affluence, mass higher education, the proliferation of new technologies of communi-

cation, and in a hundred other ways. Moreover, it must be said that the "idealism" of this "new class" though in all respects self-serving, is not for that reason insincere. It really is true that a civilization shaped predominantly by a free market—by the preferences and appetites of ordinary men and women—has a "quality of life" that is likely to be regarded as less than wholly admirable by the better-educated classes. To be sure, these classes could try to improve things by elevating and refining the preferences of all those ordinary people: That, supposedly, is the liberal and democratic way. But it is so much easier to mobilize the active layers of public opinion behind such issues as environmentalism, ecology, consumer protection, and economic planning, to give the governmental bureaucracy the power to regulate and coerce, and eventually to "politicize" the economic decision-making process. And this is, of course, exactly what has been happening.

There can be little doubt that if these new imperialistic impulses on the part of "the public sector" (i.e., the political sector) are unrestrained, we shall move toward some version of state capitalism in which the citizen's individual liberty would be rendered ever more insecure. But it is important not to have any illusions about how much can be done to cope with this situation. The "new class" is here, it is firmly established in its own societal sectors, and it is not going to go away. It is idle, therefore, to talk about returning to a "free enterprise" system in which government will play the modest role it used to. The idea of such a counter-reformation is utopian. Ronald Reagan was a two-term governor of California, and whatever his accomplishments the restoration of "free enterprise" was not one of them. Were he to become a two-term President, he (and we) would find that, after the ideological smoke had cleared, not all that much had changed.

Not Hopeless, But . . .

Not that the situation is hopeless—it's just that one has to recognize the limited range of the possible. It is possible, I think, at least to preserve a substantial and vigorous private sector—not only a business sector, but also a non-governmental not-for-profit sector—in the United States. This can happen, not because of the self-evident virtues of business, but because of the profound appeal of individual liberty to all Americans, and because of the equally profound distrust of big government by all Americans. In this appeal and this distrust even members of the "new class" share, to one degree or another. It is our good fortune that they are not doctrinaire social-

ists, as in Britain, even if they sometimes look and sound like it. They have long wanted their "place in the sun," they are in the process of seizing and consolidating it—and now they have to be assimilated into the system (even as the system will have to change to assimilate them). It will be a slow and painful business, but need not end in calamity.

A good part of this process of assimilation will be the education of this "new class" in the actualities of business and economics—not their conversion to "free enterprise"—so that they can exercise their power responsibly. It will be an immense educational task, in which the business community certainly can play an important role. But before it can play this role, business has first to understand the new sociological and political reality with which it is now operating. That, too, is an educational task of no small proportions.

Mr. Kristol is Henry Luce Professor of Urban Values at New York University and co-editor of the quarterly The Public Interest. He is also a member of the Journal's Board of Contributors, five distinguished professors who contribute periodic articles reflecting a broad range of views.

The Wall Street Journal,
May 19, 1975. Reprinted
with permission of The
Wall Street Journal, ©
Dow Jones & Company, Inc.
(1975). All rights
reserved.

THE NEW CLASS

(POSSESSES KNOWLEDGE, LANGUAGE SKILLS, AND FORMAL EDUCATION
RATHER THAN PRIVILEGED FAMILY, PROPERTY, OR ENTREPRE-
NEURIAL SKILLS)

ACADEMICS, ESPECIALLY BUT NOT EXCLUSIVELY THE HUMANITIES
AND SOCIAL SCIENCES, AND VERY RARELY ENGINEERS AND
GEOLOGISTS

TEACHERS, ESPECIALLY NON-SCIENTISTS

SOCIAL WELFARE BUREAUCRATS

SOCIAL WELFARE BUREAUCRATS

GOVERNMENT UNIONS

PROFESSIONALS, ESPECIALLY SALARIED

NATIONAL MEDIA

ADVERTISING

FOUNDATIONS

RESEARCH ORGANIZATIONS

GOVERNMENT STAFF

UNION STAFF

MAINSTREAM PROTESTANT CLERGY

MANY CORPORATE PLANNERS AND P.R. TYPES

PUBLIC SECTOR ENTREPRENEURS

SOME LABELS OF THE NEW CLASS

INTELLECTUALS
INTELLIGENTSIA
BRAIN WORKERS
KNOWLEDGE WORKERS
CLERISY
TECHNOSTRUCTURE
EDUCATIONAL AND SCIENTIFIC ESTATE
MERITOCRACY
MEDIACRACY

ETHNIC ORIGINS OF MOST OF NEW CLASS
(GROUPS WITH HIGH REGARD FOR EDUCATION)

OLD YANKEE ELITES, ESPECIALLY THE DECLINING EX-RICH

"MAINSTREAM" PROTESTANT DENOMINATIONS

CONGREGATIONALISTS
PRESBYTERIANS
REFORMED
QUAKERS
UNITARIANS
EPISCOPALIANS
NORTHERN METHODISTS

JEWS, ESPECIALLY REFORM AND SECULARIZED

HAUTE-EMBOURGEISED ROMAN CATHOLICS
E.G. JESUITS

IF THERE IS AN EMERGING NEW CLASS
IT SHOULD BE IDENTIFIED BY:

HIGH FORMAL EDUCATION
RESPECTABLE SOCIAL ORIGINS
"PROFESSIONAL" OCCUPATIONAL STATUS
HIGH (BUT NOT HIGHEST) INCOME
NON-MARKET INCOME
GOVERNMENT SALARY
NON-PROFIT SALARY
CONTRACTS AND GRANTS
RELATIVE YOUTH

KEY NEW CLASS INSTITUTIONS

UNIVERSITIES
RESEARCH INSTITUTES
GOVERNMENT STAFFS
PUBLIC INTEREST LOBBYS
OTHER NON-PROFIT ORGANIZATIONS
MEDIA CONGLOMERATES

SOME "NEW CLASS" ORGANIZATIONS

ACLU
ADA
LEAGUE OF WOMEN VOTERS
NATIONAL COUNCIL OF CHURCHES
COMMON CAUSE
NADERITES
CONSUMERS UNION
SIERRA CLUB
FORD FOUNDATION

NEW CLASS ALLIES AND CO-BELLIGERENTS

DECADENT OLD RICH
MORE RADICAL TRADE UNIONS
OLD LEFT
NEW LEFT REMNANTS
MILITANT FEMINISTS
ORGANIZED MINORITY GROUPS
BLACKS
OTHER NON-WHITES
PSEUDO-ETHNICS
(LEFT) PSEUDO-POPULISTS
"TRENDIES"
THE UPPER MIDDLE CLASS IN GENERAL

A PARADIGM OF UPPER-MIDDLE-CLASS LIFESTYLES

<u>TRADITIONAL</u>	<u>EARLY INDUSTRIAL</u>	<u>MATURE INDUSTRIAL</u>
MODEST STATUS	HIGH STATUS	NO SPECIAL STATUS
1 OR 2 SERVANTS	2-5 SERVANTS	1 OR NO SERVANTS
CRUDE SERVANTS	SKILLED SERVANTS	INSOLENT SERVANTS
EXPENSIVE GOODS	CHEAP GOODS	SHODDY GOODS
FEW SERVICES	MANY SERVICES	SERVICE "RIP-OFFS"
NO CARS, LITTLE OR NO COMMUTING	CARS, OPEN ROADS, EASY PARKING	LONG DISTANCE COMMUT- ING, TRAFFIC JAMS
URBAN NEIGHBORHOODS	SUBURBS	SUBURBAN SPRAWL
UNNOTICED POLLUTION	LESS POLLUTION	POLLUTION SENSITIVITY
LIMITED TRAVEL	TOURISM	TOURIST POLLUTION

NEW CLASS AGENDA

EXPANSION OF SIZE OF GOVERNMENT
EXPANSION OF POWERS OF GOVERNMENT
HIGHER CIVIL SERVICE SALARIES
EXPANDED RESEARCH BUDGETS
EXPANDED EDUCATION
CREDENTIALISM
"ACADEMIC FREEDOM"
"CIVIL LIBERTIES"
EGALITARIANISM
BLOCKING ECONOMIC GROWTH
OTHER ATTACKS ON RIVAL ELITES

NEW CLASS IDEOLOGY

1. PERSONAL SELF-FULFILLMENT, HAPPINESS, COMFORT, FUN,
FREEDOM, INDEPENDENCE
2. LIFE MAXIMIZATION, RISK AVOIDANCE
NEAR PACIFISM
HEALTH
SAFETY
ANTI-CREATIVE DESTRUCTION
3. "NATURISM"
ECOLOGY AND ENVIRONMENTALISM
ANTI-INDUSTRIALIZATION
ANTI-MACHINERY
ANTI-TECHNOLOGY
4. ANTI-ORGANIZATION
ANTI-CORPORATION
ANTI-NATION-STATE
LOCALISM
SMALL IS BETTER
5. ANTI-TRADITIONS AND TABOOS
RELIGION
SEX
FAMILY
SOCIAL RULES
ADVERSARY CULTURE
6. INTERNATIONAL DOUBLE STANDARD

NEW CLASS AGENDA

EXPANSION OF SIZE OF GOVERNMENT

EXPANSION OF POWERS OF GOVERNMENT

HIGHER CIVIL SERVICE SALARIES

EXPANDED RESEARCH BUDGETS

EXPANDED EDUCATION

CREDENTIALISM

"ACADEMIC FREEDOM"

"CIVIL LIBERTIES"

EGALITARIANISM

BLOCKING ECONOMIC GROWTH

OTHER ATTACKS ON RIVAL ELITES

Appendix B

HISTORICAL PERSPECTIVES FOR SPACE DEVELOPMENT

I 2084: SPACE AND SOCIETY IN THE TWENTY-FIRST CENTURY

For the examination of space and society in the twenty-first century the year 2084 has been selected as the target date. Any selected year is arbitrary; 2084 was chosen because it will be about a century from the production of this report, and because of the literary connotation--it is by reference to George Orwell's 1984.

The preliminary treatment of the subject is to treat "society" and "space" as independent invariables; This is merely a hypothesis, not a conclusion, and will be modified in the detailed examination. This is done consciously, partially because of some skepticism of overblown claims often made for the effects of technology on society. Although it is true that "technology" (collectively) has had an extraordinary effect on "society" (collectively), at least during the last few centuries, yet it is, as will be argued, exceedingly difficult to see very many examples of individual technologies having extraordinary effects on society collectively and certainly not rapidly.

To be sure, the hypothesis may itself be excessively influenced by recent history whereby technological change has clearly been gravely restrained, retarded and diverted by social pressures expressed through politics. The best example is, of course, the American space program--the technology has been available to for example, begin preparations for a manned mission to Mars, for example, yet the social support and therefore the funding were not present. This kind of choice often is a complex and difficult matter that will be expanded upon subsequently. For now forecasts for society and space will be made separately and the integration done later in this section.

A. Society

By "society" is meant the total system of human relations of an era. In the absence of knowledge of extra-terrestrial societies, it is a global society that is being contemplated. This concept seems banal, except that it is necessary to point out that a global society has only recently been achieved. Only in the last generation can it truly be said that all human beings on this earth interact with one another in some way. (Perhaps a few hundred tribesmen in the Amazon are holdouts, but they will not last long.)

To discuss, much less to understand, contemporary global society in a satisfactory manner is simply impossible, beyond human capabilities. Agreement cannot even be achieved upon what are key parameters. So it is necessary to recognize human limitations and simplify extraordinarily. But this does not limit the opportunities to improve our general understanding. To use an analogy from art, no one can reproduce any existing human being, yet the artist with a few lines of graphite on a sheet

of processed lumber can depict what is clearly a recognizable person. Because it is recognizable, it is discussable and understandable. A method used at the Hudson Institute to limit possible and useful future societies is the study of "alternative world futures."* Herman Kahn has admirably outlined the objectives of this tool:

1. To stimulate and stretch the imagination.
2. To clarify, define, name, expound, and argue major issues.
3. To design and study alternative policy "packages" and contexts.
4. To create propaedeutic and heuristic expositions, methodologies, paradigms and frameworks.
5. To improve intellectual communication and cooperation, particularly by the use of historical analogies, scenarios, metaphors, analytic models, precise concepts, and suitable language.
6. To increase the ability to identify new patterns and crises and understand their significance.

This methodology has been used in various ways over the years. Experience has taught us that it is wise to employ a small number of sets of alternative futures for very simple, practical reasons. If a single future is presented, that is taken as a forecast, which is not the intention. If two alternative futures are presented, this sets up the terms for a two-sided and contentious debate (although we have occasionally created two such futures for exactly that purpose); if three are selected, then the normal response is to take the middle one as the "medium" and the most likely. Four futures eliminates that problem, but reintroduce the disputes about the middle two. Five futures has the same problem as three plus the additional disadvantage of excessive elaboration; and six or more futures bogs one down in unmanageable materials. Clearly, four alternative futures is preferred if there is no most-likely scenario. Nonetheless, so far in our research we have found it sufficient to make do with three (or as we shall see three and a half) global social futures.

It should be clearly understood that these are imaginative constructs. They are not "scientific" calculations, as the word is commonly understood in the late twentieth century. Nonetheless, they are not fiction (even science fiction) because they rest firmly upon three fairly substantial empirical legs. The alternative future worlds must be:

1. Consistent with what is known of scientific "laws" as understood today (but it would be most surprising if those laws were not modified in the next 100 years).
2. Consistent with established patterns of human behavior. Granted, this is a somewhat shaky leg because there is by no means widespread agreement about what constitutes established human behavior. For example, marxists and other utopians argue that certain aspects

*Herman Kahn, The Alternative World Futures Approach. Hi-787-RR.

of human action, especially less pleasant ones, are not inherent in the human race, but are a necessary output of certain economic and social institutions. We can partially handle this objection by reference to our third leg:

3. Not unrecognizably different from the world of today. This leg is kept in place by the relatively short timeframe of the exercise. On the record, a century is not sufficient time to fundamentally modify human behavior. This argument is made by analogy. The year 2084 is as distant as is the year 1884. Certainly, there have been many changes in science and in society since the year 1884, but it is not unrecognizably different. We could travel to 1884 and feel quite at home there, at least in its advanced economies and among its upper classes. And while this is necessarily conjecture, it is not difficult to imagine that many people from 1884 could come to 1984 and fit in rather nicely indeed. Certain things would amaze them, but people are extraordinarily adaptable. A piece of supporting, but not conclusive, evidence of this speculation is that very primitive people, people who effectively live in 1584, can be brought in from the bushes, and manage to do commendably well in our society; they will not be theoretical physicists, but can live and do useful work among us. To reiterate, we should consider that 2084 will be different from 1984, but not inconceivably different.

Clearly the third leg of the triad of support implies that the alternative future worlds will be related in some way to our own, and this is a correct assumption. They are derivations of the present world and therefore are in a sense forecast or projected from our world. But the projection is not made in any mechanical way. They are rather more of an a priori nature than of a projection. Always with 1984 in our minds, we will draw up alternative future worlds of 2084, being careful (we hope) to make those worlds internally consistent and reflective of the three basic principles of construction mentioned above, but nevertheless these are intellectual constructions primarily.

We have labeled these worlds with Greek letters which are keyed to the proper names of writers whose works have contributed to suggesting these worlds to us:

1. Kappa. Kappa is from Kahn, Herman Kahn, who was the leader in developing the methodology employed here and who with his associates (including these writers) developed and elaborated a fairly consistent and plausible vision of the future of mankind. This is perhaps most familiarly expressed in what Kahn called "The Long-Term Multifold Trend" (Table B-1).

The use of the Multifold Trend will be elaborated in our description of the Kappa world. It may be useful to note at this time that certain tendencies will be held to be of great importance in the twenty-first

*The first widely available version of this was in Kahn and Anthony J. Weiner, The Year 2000 (New York: 1967), p.7. Our version is from Kahn and Bruce-Briggs, Things to Come (New York: 1972), pp. 8-9.

Table B-1

THE LONG-TERM MULTIFOLD TREND OF WESTERN CULTURE

1. Increasingly sensate (empirical, this-worldly, secular, humanistic, pragmatic, manipulative, explicitly rational, utilitarian, contractual, epicurean, hedonistic, etc.) cultures
2. Bourgeois, bureaucratic, and meritocratic elites
3. Centralization and concentration of economic and political power
4. Accumulation of scientific and technical knowledge
5. Institutionalization of technological change, especially research, development, innovation, and diffusion
6. Increasing military capability
7. Westernization, modernization, and industrialization
8. Increasing affluence and (recently) leisure
9. Population growth.
10. Urbanization, recently suburbanization and "urban sprawl"--soon the growth of megalopoli
11. Decreasing importance of primary and (recently) secondary and tertiary occupations; increasing importance of tertiary and (recently) quaternary occupations
12. Increasing literacy and education and (recently) the "knowledge industry" and increasing role of intellectuals
13. Innovative and manipulative social engineering--i.e., rationality increasingly applied to social, political, cultural, and economic worlds as well as to shaping and exploiting the material world--increasing problem of ritualistic, incomplete, or pseudo rationality
14. Increasing universality of the multifold trend
15. Increasing tempo of change in all of the above

century. To reverse the order, consider No. 14, "Increasing universality of the multifold trend." We expect that in another century what is generally called the industrial revolution will have been completed; that is, all of humanity will have access to the system and nearly all countries will by historical standards be substantially richer--although, if the attitudes of the prosperous in today's world are any measure, they will be less than satisfied with their prosperity. This trend is also reflected in No. 7. On the question of increasing affluence (No. 8) we will make rough estimates of world and major national economic products. These can be astoundingly high figures, even assuming moderately growth rates, probably factors of 10 to 50 greater than current GNP for most nations. Indeed, our projections will show enormous numbers even though we forecast a slowing down of growth rates, especially in the advanced nations. (The reasons for the slowing down are twofold--first technical, in that before long the very high early growth rates of been a transition from an agricultural to an industrial society can no longer swell the world growth figures. We note that much of this change has statistically misleading, as the conventions of GNP accounting tend to disregard the product of subsistence and household economies. As families move into an exchange economy a greater fraction of their output appears in the national income accounts. But probably more important as a drag on economic growth will be a perception of a declining marginal utility of prosperity. The rich have, on average,* less need for the next increment of production than have the unrich.)

No. 6, "Increasing military capability," is of obvious concern to space futures, as are numbers 4 and 5 before it.

In its larger framework the Kappa world will look very much like that of today. This picture is more than merely a "conservative" forecast. It reflects the evident fact that Western civilization seems to be running out of new ideas for economic, social, and political organization. The late twentieth century has shown very little that is "new" outside of certain important technological areas. The dominant themes have been disillusionment with many of the programs and nostrums of the past, to use Daniel Bell's phrase, "an end to ideology," and a succession of revivals of old ideas, spuriously labeled by their promoters as "new"--most of these are better labeled "neo-," a new version of.... Thus, the Kappa world will assume the survival of the nation-state, but with considerable international and subnational organizations. Indeed, the most probable political forecast will be a very slow evolution toward something more resembling the Middle Ages than the Nineteenth Century. Instead of a world system of discrete sovereign nation-states rather like the Greek image of the atom, there will be a devolution of some powers of the nation-states upward to international organizations and downward toward subnational bodies. The EEC is an excellent example

* This slowing growth hypothesis is developed in detail in Kahn, William Brown, and L. Martel. The Next 200 Years (New York: 1976).

of what we mean. Another is the Arab league. Various international space corporate bodies may soon offer other examples. All manner of structures of international cooperation can be expected. Another variant is the present relations between NASA and foreign space programs whereby there is a single-nation-dominant cooperative venture. Nonetheless, despite these changes, we would be very surprised indeed to see the nation-state seriously modified from its dominant locus of power and the loyalty of its inhabitants.

2. Delta. The Delta world takes its name from the scientific popularizer Rene Dubos, who in our judgment is not only a good thinker in his own right, but can stand as a representative of many writers, and more important many more individuals, who have an optimistic view of a future informed by technological knowledge and secular idealism. Such people view the nation-state and traditional loyalties as primitive and atavistic and look forward to--not in any cr-oot utopian sense--human evolution toward higher spheres of ethics and behavior. Although it is important to be skeptical about such forecasts--in part because it seems to universalize the internal values of an elite university or a research institute--nevertheless we see it as very much within the realm of human possibility and note that many very serious people in powerful places of influence are working diligently toward its achievement. Such people, we believe, make up the bulk of the intellectual staff of the Western arms control movement. They are not subversives, fools, or crazies; they are informed by a desire to work toward a world without war and a world not ruled by threats of brute force.

The Delta world is also consistent with the long-term multifold trend outlined above, but puts more emphasis on certain aspects of it--in particular the first five items on the list. This world is to some degree a technocracy, to some degree a world dominated by the views of irreligious scientists as first seriously outlined by August Comte and the other Positivist disciples of Saint-Simon in the early nineteenth century in France.

We have to speculate on whether or not this world will be richer than the Kappa world. On one hand it ought not to be as rich because this society should care less about money and material possessions. But on the other hand, the heightened role of the scientist and technician and lesser amounts of money spent on armaments might more than counteract the first factor. Considerably more thought needs to be given to this matter.

3. Beta. This world is named after James Burnham, the American political figure who amalgamated and popularized the works of Marx, Trotsky, and the hard-minded reactionary social scientists of the turn of the century (whom Burnham labeled "the Machiavellians"). His most famous work was The Managerial Revolution, which, appropriately, was a primary source for George Orwell's 1984. The Beta world is a world of continued discord and strife. In the Beta world we expect that No. 6 "Increasing military capability" and No. 13 "innovative and manipulative social engineering" would be dominant. As forecast by Burnham in The Managerial

Revolution, all societies are increasingly dominated by the hierarchies of "managers" answerable mostly to themselves and in continuous struggle with managers of other institutions for material goods, power, and prestige--but power most of all. This is a world which is not unfamiliar to us, and especially to those who frequent the precincts of great international capitals and of other large institutions. This is not the world of Orwell's 1984--we do not expect a system as ongoing and competent as his nightmare. This is a world in which most people continue about their business relating themselves to their private lives much as they do today, yet it is also a world in which there is a marked withdrawal from public life, a decline in the idea of citizenship, and a heightening of cynicism. It is also a world, of great organizations that choke out or dominate those around them. Whether it is nominally "socialist" or not, in a considerable sense makes no difference; the managers can disregard "the people" just as easily as some can now disregard the "shareholders".

In a considerable sense, the Beta world differs from the Kappa world in the opposite direction from, and roughly in a mirror image of, the Delta world. Both worlds are "materialistic" but the Beta world is more cynical, selfish, and goods-oriented as contrasted with the increased emphasis on a more "idealistic," although equally selfish Delta world.

3½. Gamma. Gamma is for Gibbon, Edward Gibbon, historian of The Decline and Fall of the Roman Empire. This we mention but do not expect to elaborate in detail, for reasons which will soon become evident. The Gamma world #1 is that of Decline and, according to the schema of the great macrohistorians such as Spengler and Toynbee, a "universal state" or "civilization-wide empire" is a mark of decline. because a world imperium (command) cannot be effectively operated by the United States and certainly not by any other liberal democratic state, the organizing authority for the world imperium must be the Soviet leadership (the best candidate), Chinese leadership, perhaps Japan, or some other power which has not yet appeared; although this last seems most unlikely.

Gamma world #2 is that of Fall, the collapse of civilization, the reduction of the world society to a litter of poor, beastly tribes in the model of the Dark Ages of Europe following the collapse of the Roman Empire in the west. Such is a reasonable outcome of a major multi-combatant thermonuclear war.

Both of these worlds (Beta and Gamma) have very interesting space-related implications. Scenarios for achievement of the Fall world derive easily from nuclear proliferation, the relative decay of the United States and other stabilizing powers, and the ready availability of cheap, reasonably reliable long-range weapons.

The decline world of a world imperium also is made more likely by certain developments in space technology. The principal problem of

operating a very large tyranny is that the rulers must create an expensive and untrustworthy security apparatus which eventually will turn on them. Space-based intelligence and weapons systems make it possible to police the world with a small number of technicians. Reconnaissance satellites can detect almost any sort of serious hostile activity, and space-based directed energy or other precision weapons can easily execute surgical, general or random reprisals against dissident sections. There would be less need for "spooks," praetorian guards, or any other potentially disruptive security forces.

We do not elaborate further on the Gamma worlds because they are not policy-relevant to the American space program. To say the least, NASA ought not to be concerned with speculations about the destruction of technology or the supercession of the American republic. We expect that the three worlds outlined earlier will provide some of the alternatives useful for analysis of the prospects for space developments.

B. Space

Of course, "space" is used in its popular meaning--human and/or automated activities in orbit around this earth or beyond. Initially, we made a single "surprise-free" projection of the potentials for space up to the year 2076. Drawing on our previous work, updating and modifying it where necessary and appropriate, our surprise-free projection for space capabilities and activities on the Moderate Scenario is roughly consistent with the Kappa world. This forecast initially reflects technical achievability, but necessarily is heavily modified by the needs and goals of society, so the projection for space becomes integrated with that of society; that is, we attempt an informed speculation on what society will permit and expect of space.

C. Space and Society

In addition, while initially constructing our materials as independent variables, then letting society drive space, the possibilities for space driving society will also be examined--for space activities feeding back to earth society and modifying it. Here the method must be speculation, but it also can be informed in a useful way by historical analogy.

The metaphor "frontier" is often used for space, so we look next at the effects of previous frontiers, both territorial and technological. The richest material, we expect, will derive from examination of the expansion of Europe across the seas in the early modern age. Of great significance to this study is the theories of the Texas historian Walter Prescott Webb who posited that there was in the early modern period up to about 1900 a "Great Frontier" whose existence, wealth, and spirit greatly influenced the "Metropolis" of Europe. Other frontiers will also be identified and examined, but it is doubtful if any of them will be as relevant to our purposes as Webb's Great Frontier.

The second body of historical analogy useful to our purposes is that of technology. And the most promising are the frontiers whereby transportation technology permitted the better exploitation of a previously difficult or impossible medium. Related to the Great Frontier is the development of effective intercontinental sailing ships which allowed the exploitation of the ocean medium. Also worth at least a look is the railroad which had almost equally revolutionary effects upon land media which were difficult of access because of their inherent qualities (deserts, mountains, steppes) or mere transcontinental distances.

More familiar to us is the exploitation of the air frontier. Within the memory of men now alive, machinery has been devised which permits the conquest of the atmosphere, a major industry has been built up, and profound changes have been achieved in the world. This is especially relevant and interesting to those in space activities because of the interrelationship of personnel and of institutions into what has been labeled "aerospace" (but whether this near unity is likely to be continued is an interesting question of futures research).

From this combination of analytical exercises--alternative future worlds, surprise-free projections, and historical analogy, it should be possible to produce a rich body of material regarding space and society in the twenty-first century that should help to stimulate the thinking of responsible officials in the late twentieth century.

II. FRONTIERS IN TIME AND SPACE

This section is an attempt to improve the understanding of the potential effect of space exploitation upon earth's society by employing historical analogy. Our concept is to take literally the metaphor of space as a "frontier," examining the effects of the previous physical and technological frontiers upon their societies. The approach is prompted by the idea of the great Texas historian Walter Prescott Webb; his The Great Frontier (Austin, Tex., 1952) expanded the "frontier hypothesis" of the American historian Frederick Jackson Turner to all of modern history. In addition to the Turner concept that the frontier experience substantially modified European civilization in its transfer to America, Webb argued that the overseas frontier of Europe in the early modern age made fundamental changes on European society itself. Webb's work in many ways falls short of the highest standards of historiography because he was not thoroughly informed about European society and was rather carried away by his enthusiasm for the frontier thesis; nevertheless, the concept and the terminology is relevant to the central concerns of a space frontier.

To Webb, the term "frontier" is not used in its European sense of a clear-cut legal boundary between separate jurisdictions, but as a zone to some degree accessible to and used by men, which is adjacent both to the already settled versions and to the unoccupied wilderness beyond. The frontier, therefore, is a moving concept. A second Webbian term is "the Metropolis," by which he means the original settlement. Of course, the analogy in space exploration is the Earth as Metropolis and those nearer portions of extraterrestrial space which are being used by mankind in some way as the frontier. Beyond the space frontier is of course the wilderness, which can be called "deep space," recognizing that this is a concept which will gradually recede from Earth as this space frontier advances.

A flaw in Webb is his limiting of the frontier discussion to overseas land activities. It is well to keep in mind that until the beginning of the modern age, circa 1500 A.D., Europe (as it is just coming to be called--the previous label was "Christendom") had a land frontier to the east which was largely a military frontier against the steppe and a clearly military frontier to the south against the highly organized and formidable forces of Islam. (We might recall that Columbus's first expedition set sail the same year as the liquidation of the last Moslem outpost in Spain.) But to the west was a sea frontier.

A. The Sea Frontier

To Medieval man the Atlantic seemed as difficult an obstacle as was the air in the nineteenth century and space in the early twentieth

century.* To be sure, the Vikings, using very primitive sea-going technology, succeeded in reaching Iceland, Greenland, and even effecting a short-lived lodgement on the North American continent. This was a dead end, for reasons which are not entirely clear. However, it and ruthless pirates whose greed and fighting spirit sent them east to Muscovy, Constantinople, and Persia; south to England, France, and around Gibraltar into the Mediterranean; as well as west across the Atlantic. Advances on all of these axes halted at approximately the same time, about the year 1000, which was also approximately the time that these pagans were converted to Christianity. The point here is that technology, however important, is not the only factor involved. There was no retrograde movement in Scandinavian shipbuilding and navigation technique. Something happened to the will of these "gangs" which made them halt their viking. It is well established that there was a climatic change, at least a little later on in the Middle Ages, which made sailing the North Atlantic a more difficult exercise. That change so demoralized the economic life of Iceland that these proud people had to become a sort of Puerto Rico to Denmark. Also it essentially wiped out the Greenland colony.

Be that as it may, the abortive trans-Atlantic effort was followed by a successful one a half-millennium later. The late Middle Ages saw an incremental evolutionary development of blue-water shipbuilding techniques relying upon increasingly complex use of sails as well as the gradual improvement of hull design through generations of empirical experimentation. In addition, a series of minor but cumulatively important breakthroughs in navigation permitted credible at-sea location and direction finding--of course, the basis of the navigational technology was one of the first practical exploitations of space: the calculation of the position of the ship relative to the stars. Another breakthrough was the exploitation of a magnetic phenomenon: the compass.

Within a generation on either side of 1500 A.D. a transocean breakout from Europe occurred. The Atlantic barrier had collapsed. The sea frontier jumped across oceans, not merely across the Atlantic to North and South America, but also southward around Africa to "the Indies." The key "missions"--the Sputniks and Apollos of that era--were Christopher Columbus's passage of the Atlantic in 1492 and Vasco Da Gama's voyage to India in 1496. Both of these had been prepared by a series of preliminary missions. Portugal was the leader in promoting transoceanic exploration. It is striking, especially considering the enormous differences between those societies and our own, how similar was the institutional mechanism for sea exploration to that of space. There was a complex interplay between

* General remarks are based on wide reading in primary and secondary sources of the period. Reference was made to these works for this paper: S.F. Morison, Admiral of the Ocean Sea (Boston, 1942); Morison, The European Discovery of America (Boston, 1971 & 74); A.L. Rowse, The Expansion of Elizabethan England (New York, 1955). A superb summary is J.H. Parry, The Age of Reconnaissance (New York, 1964). Atlantic.

the expedition promoters, syndicates of profit-motivated investors, and the governments of that time. There was, if you like, a sea-industrial-complex, or a sea-trade industry. Furthermore, a minor point but one which is impossible to resist noting: Italian captains played the same role around 1500 as German rocket scientists around 1950--and in both cases, a generation of national specialists was quickly replaced by native talent.

Now, what did these sea venturers want and what did they expect from their efforts? We may assume that to some degree they were motivated by mere curiosity and adventure, although this was not in those days considered to be a legitimate ambition and has not, to our knowledge been so reported. To obtain the necessary support for their venture, they needed more serious reasons. The first was money. One of the major ambitions for overseas trade was the observation of the enormous prices that could be obtained for transoceanic goods in Europe. The vaunted spices and silks of the East sold in Europe for extraordinarily high prices because of the high transportation costs, considerable risks of the Levantine route, and the large numbers of middlemen. Anyone who could find a low-cost route to the Indies could count on picking up huge windfall profits from exploiting these price differentials.

The second motive, although related, was also money--but for a very different reason, for what we would now call "national security." In those days, money played the role in war similar to what technology does today. In the modern world we take it for granted that the money will be available at least to pay the troops and provide them with basic equipment--such was not the case in the early modern age. The idea of nationalism had hardly emerged and a soldier or a sailor considered himself to be a working man who had every right to be paid. Those military workers had considerable experience in the unreliability of governments to meet the obligations to their forces. Troops and ships had to be paid and paid for in specie--in gold and silver. No specie, then no troops, no ships, no guns.

The early sea frontiersmen were extraordinarily fortunate. The discovery of the route to India paid off immediately., Vasco Da Gama's voyage is reported to have returned 600 percent on the investment. Exploitation of the India route made Portugal, previously a minor country on the edge of Europe, a world power. Eventually the Portuguese were displaced by the Dutch, who also prospered on the India trade.

To the rest, the windfall did not come immediately. The initial English and French expeditions had no positive results. Columbus's voyages were a disappointment and the conquest of the Caribbean returned little to Spain. But Cortez and his followers hit a mother-lode of gold and silver in Mexico, and this was followed up almost immediately by Pizarro's strike at Peru. Specie beyond belief was collected.

These rapid windfalls from the sea frontier stimulated further efforts for generations to come. The success of finding the southeast passage to the Indies led generations of explorers to seek a northwest passage across America to China and Japan. The wonderful success of the Mexican and Peruvian expeditions prompted generations of explorers to seek other El Dorados in the Americas and in Africa. That these further efforts came to naught is of less interest than the importance of the initial strikes in keeping the process going. For instance, had the Vikings hit something so extraordinary in North America, perhaps their momentum would have been maintained.

The point here is that this experience suggests that one of the most attractive possibilities for the space frontier would be to shortly locate such an immediate "windfall" of a direct and immediate return on something which is of vital interest to at least the dominant classes of the metropolitan earth society. It is fair to comment that so far a windfall on this scale has not been achieved. For instance, the utility of military reconnaissance in space is obviously desirable but is not yet of the needed level--it may be roughly equivalent to the utility that oceangoing ship technology had in the design of warships for combat in European waters--desirable, but not decisive. The same can be said of space-located communications--nice but not a windfall. What it might become is necessarily conjectural--one cannot plan for a windfall. However, following the analogy of the India route and the American expeditions a space windfall could take the form of something of extraordinary value finding in space. Or, perhaps by an ability to perform some new processes in space some things of very great value to earth might be made much below their earthbound costs. An asteroid of precious metals is a simple example. More likely are process possibilities must be noted that the Scandinavian Vikings were extraordinarily vigorous. F. Braudel, Capitalism and Material Life: 1400-1800 (New York, 1973); which would be extraordinarily expensive or impossible down-here. For example hormones and other biologicals that can prevent or cure most of the major diseases.

A "windfall" can be defined in economic terms as a drop in cost of several orders of magnitude. Such a cost cut can have marvelous ripple effects. For example, suppose pure diamonds of any desired size or shape could be made cheaply in space. Many manufacturing processes on earth could be revolutionized to society's benefit. Or if pure crystals for advanced computer chips can be made reliably and inexpensively it could revolutionize (once more) the computer industry. Many other possibilities exist and even now may be in the minds of inventors.

What were the short term effects of the sea frontier upon the Metropolis? The effects on the military balance in Europe were precisely what the promoters of exploration had hoped for--an extraordinary shift of power towards the sea-entrepreneurial states. Portugal and Spain amassed immense wealth which they invested in armies, navies, and seemingly

interminable wars. Spain in particular was transformed from a secondary power on the corner of Europe to the European superpower which projected its might to the Netherlands, to Germany, and up to the shores of England. Unfortunately for the Iberian states, they had no thought of investing the money, lacking theories of development such as those which motivated most countries which recently obtained an oil-profit windfall. The Iberian countries shortly went into decline, as their aggressive ambitions outstripped even the extraordinary means provided for them by India trade or the mines of Mexico and Peru. The wealth was dissipated to Dutch shipbuilders and to Italian, German, and Belgian mercenaries and their hangers-on.

The rapid influx of money into Europe had extraordinary and unanticipated effects upon the economy. An enormous inflation was set off by the augmentation to the money supply. Many theorists of the relationship between economics and culture (most notably Lord Keynes) believed that this "monetary illusion" of steadily increasing prices created a sense of enthusiasm and a positive vision of the future which was a major factor in the conversion from the medieval to the modern age. This is a reminder of the obvious--that the opening of a new frontier is bound to have untoward and incalculable consequences.

The next consequence of the opening of the sea frontier was to bring into Europe things which were not known before. The Americas in particular contributed exotic fauna and flora. The Europeans first treated these as curiosities, but gradually learned to adapt and use them for their own purposes. Tea and silks from the East had long been known, but their extraordinarily high prices had made them luxury goods; now the price dropped and made them available to the middle classes. From America came corn (maize), potatoes, and, of course, tobacco. These new products revolutionized the consumption patterns of Europeans, but of course very slowly.

After the exploration/conquest phase came the colonization of the frontier. People came to live there. At first the inhabitants were only temporary sojourners, intending short-term residence merely to make fast money to bring back to the Metropolis to spend. This was a risky matter. As late as the early nineteenth century an ambitious man could go out to India to make his fortune with less than a 50-50 chance of surviving the trip and the tropical diseases, but life was risky at home as well. We still see this pattern existing today in the mining camps and oil fields in land frontiers along the Arctic and, for Europeans at least, in the tropics of South America, Central Africa, and the East Indies. High wages have to be paid to draw people to unpleasant and faraway places and those wages can only be justified economically by some activity which is more profitable there than elsewhere.

In American history, the most striking example is the short but glamorous career of the mountain men who trapped for furs, especially

beaver, in the Rocky Mountains and Pacific Northwest in the early nineteenth century.* The characteristics of these men is worth noting--they tended to be fierce individualists, rather less-than-satisfied with the boredom of more settled places. They were also young. The careers of such men are inherently tragic, because the frontier will always catch up with them and because they age and become more sedate (as test pilots becoming businessmen). And--here is a caution for space exploration--the market may change. The mountain men were wiped out by a change in European fashion from the beaver hat to the silk hat. Whaling was sort of a frontier activity attracting much the same sort of men, but that business was killed by the discovery of coal distillation and the replacement of whale oil by kerosene for home lighting. But the possibility of obsolescence by fashion change or technological innovation is a risk of any business in the frontier or in the metropolis.

The next stage in the occupation of a frontier is the beginning of permanent colonization. Why would people take a great deal of time, money, and risk crossing a dangerous ocean to start a new life in an unoccupied land? For most of them, the principal motivation was a simple desire to improve themselves, by the standards of the metropolis; that is, they sought to replicate on the frontier the life of the privileged classes back home. Many of these colonists, especially those in the Iberian colonies, were younger sons of the upper classes who lacked economic opportunity at home and therefore had relatively little to risk from trying to become grandees abroad. However, a landed gentleman required plentiful ill-paid and vassal labor. This was available in the peasants of Europe, but why should they cross the ocean to remain near-serfs in an unfamiliar country? The colonists solved the problem by reducing the native population of Indians to serfdom, and where there were no Indians, or where the Indians were so primitive and proud so that they would rather die than work, the native population was liquidated and replaced by African slaves imported for that purpose. This paragraph may seem a little irrelevant to issues of space colonization, but it is not: it teaches us that people will not go into space in order to wash equipment and scrub floors. Some other institutional or technical means of doing the dirty work in space must be established. Robots are the most obvious candidates. Perhaps alien life or genetically-created forms that could be trained is another.

The attempt to replicate the social life of the metropolis on the frontier had mixed results. The necessary modifications of social life to accommodate the conditions of the new world have been the favorite stuff of the frontier historians. Things never worked out exactly as they did in Europe. But on the other hand, apart from the changes necessary to accommodate to a revised servile class, the new conditions were usually not all that different either. Our contention is that frontier theory exaggerates the changes. Yes, the language modified

*David Lavender, Bent's Fort (Garden City, N.Y., 1954).

slightly in that American English is different from European English, ditto French and Spanish and Portuguese. Of course, the complexity of social life and institutions of Europe was simplified as these were transplanted across the ocean. Yet, the colonists held the same standards as those of the metropolis, and by those standards saw themselves as inferior to their equivalents in the metropolis. This perception was more than shared by the ruling classes of the metropolis who saw the colonials as uncouth provincials. These perceptions were correct. Colonial society was narrow, almost cultureless and unproductive except in a strictly material sense. It was centuries before the transoceanic colonies of Europe produced metropolitan-class scientists, writers, performers, or artists. "Who reads an American book?" asked an English critic in the early nineteenth century, just before the first great generation of American writers appeared. Nevertheless, this question quite properly applied with a few minor exceptions to the previous two and a half centuries of overseas English colonization.

Conversely, there seems to have been little effect of the new world upon the imagination of the metropolis. This is necessarily indeterminate, but where are any concrete examples whereby experience of the frontier or the existence of the frontier had an effect upon European culture or science? American scholars have delved into this subject at considerable length and come up with such trivia as the setting of Shakespeare's The Tempest in an imaginary Bermuda, but mostly bits and pieces of references of that sort. Now, it may be that there was an opening up of the mind caused by the knowledge of a great unknown external world which helped to upset the medieval world view and caused the opening of the modern scientific world view. This cannot be proved or disproved and the curt treatment of this subject in no way properly reflects on its possible importance. Still, other factors were clearly involved. We recall that the Protestant Reformation opened in the generation after Columbus and Vasco Da Gama, but it seems incredible to make any sort of intellectual or socio-psychological link. The period which we called the Renaissance, of course, evolved in northern Italy, at the very center of the highly developed and prosperous Mediterranean world, far from any frontier.

We should not ignore two other important groups which found their way to the frontier. These were from opposite ends of the spectrum of human character. U.S. history in particular glorifies a handful of individuals who came across the ocean for essentially ideological reasons--to create pure religious communities untainted by the corruptions and repressions of the old world. They had a conscious vision of building a new world. The importance of these small groups cannot be underestimated, but it must be remembered that they were a minority of the colonists even in their own settlements. Space would seem to offer extraordinary opportunities for small groups who wished to get away from it all and to establish something truly new. Still, we should recall that there are still plenty of places on this earth where this can be done with a great deal less expense and difficulty.

A second minority group that came to the frontier was criminals. Actually, the line between the explorers/conquerors and criminals is a very fine line indeed. Many of these fellows spent considerable time under the supervision of the law in the old world, partially for being general troublemakers. (Cadillac, the founder of Detroit, lived longer in the Bastille than in the city that he named.) Many of the frontiersmen were on the run.

And worse, the frontier was looked upon by the metropolis as a dumping ground for its criminal elements. Hundreds of thousands of convicts and political prisoners were shipped from England to America, and when this human dump was closed by the American Revolution, to Australia. The Soviet Union is still using this technique on its Siberian frontier. Space as a place for troublemakers to flee and/or to escape the bounds of civilization and/or as a site for penal colonies is not likely to be an attractive prospect to space promoters, but is not beyond the realm of possibility either.

Let us turn now to the later development of the overseas frontier: First, the fundamental transportation technology evolved but slowly. Navigation technology and technique was developed incrementally until the point at which it could truly be described as "scientific." The vehicle--the sailing ship--similarly evolved, becoming larger in size, more rapid in speed, and more elaborate. But it was necessarily limited by speed of the wind and the strength of materials. Still, it must be remarked that a full-rigged sailing ship of the early nineteenth century was probably the most complicated piece of machinery that man has ever operated and perhaps ever will. It was dangerous and complex and required extraordinarily close coordination and superb skills. Not until steam power substituted for sail did the enormous transoceanic migrations become possible in the late nineteenth century, resulting in the restriction of immigration to the United States and other transoceanic settlements. And, of course, the twentieth century saw long-distance air travel which not only permitted swift immigration but an equally swift return to the home country.

It may be reasonable to speculate upon the long-term effects of this analogy to space exploration. This is of course not to claim that any such things will happen, but they might. The analogue of the sailing ship era is the rocket age. We could expect a considerable period of improving yet fundamentally inefficient space travel by rocket for some period of time, for centuries if the transoceanic analogy were perfect. Then an improved technology, one which was not previously conceived of, would give much greater speeds and cheaper costs--and we are not here thinking of the hypothetical "hyperdrive" (the faster-than-light travel of the science fiction writers) but something that would, say, increase propulsion efficiency by an order of magnitude, and reduce costs by about the same ratio. Concurrently with the development of improved transportation technology would be the achievement

of a true independence of the space colonies, but in a system in which they were in close and intimate relations with the metropolis on earth as the transocean settlements are to Europe.

The economic function of the colonies evolved but very slowly. But on the whole they were highly specialized and intended purely to provide specialized goods to the metropolis. They had to have an extraordinary advantage in some factor of production in order to thrive. The price of labor was always much higher in the colonies because of the cost of bringing it across the Atlantic as well as the risks and general unattractiveness of colonial life for working people compared with their familiar haunts in the Metropolis. The factors of production in which the colonies exceeded the Metropolis were either their undeveloped and therefore fertile soil and/or special climatic conditions which offered opportunities to grow cotton, sugar, cocoa, indigo, and other specialty goods. (Note that they were usually tropical goods unavailable in Europe.)

Another factor forcing the economic specialization of the colonies was the mercantilist theory then enforced by the European states which controlled and protected the colonies. As noted earlier, the early modern equivalent of technology was money, and the purpose of economic policy was to accumulate gold bullion in order to hire forces in wartime and thereby to expand one's territory. Having a nearly self-sufficient empire meant that one need not export bullion in order to gain necessary goods. Related to the national security intent of the metropolitan countries was the desire to secure necessary raw materials for the war machine itself, in particular iron and "naval stores"--tree trunks for masts, hemp for ropes, and the like.

Although it is arguable which influences were the most important in shaping the economic life of the colonies--"natural" economics or state policies--a strong case can be made that the state policies were a poor second. Nonetheless, the fact is that colonies were an unbalanced and to a certain degree artificial economy necessarily reliant upon the mother country in the Metropolis. It is to be expected that this will be at least the initial condition of any in space or trans-space colony. Prosperous colonies might want to return "home" to enjoy the full spectrum of social, cultural, and economic life.

It took quite some time in colonial development before a colony developed a social life of its own which could compete successfully with the mother country in the Metropolis. For the United States this occurred about 1800, for Canada about 1850 and later for the rest of the British colonies. It was not until quite late in the Nineteenth century that the Spanish and Portuguese colonies of Latin America achieved a similar relationship relative to their mother countries. Quebec has not and probably never will achieve parity with the mother country of France. The principal determinants are the most basic ones: gross economic power and size of population.

Although the colonies were intended to be specialized units supplying the metropolis with specific products, they gradually became filled with rather ordinary people. We know little about these people except that they must have begun with exceptional traits to cross a dangerous ocean in order to enjoy a less civilized way of life. Most of them became subsistence farmers. They operated self-contained economic units feeding themselves and exchanging a small surplus for a few outside goods. In other words they lived pretty much as the peasants of the old world had. A much smaller group similar to some in Europe were the craftsmen and various other artisans who served the merchants, the planters, and the "peasants". Over time these ordinary occupations expanded until they constituted a market in and of themselves. It was roughly at this time that the colonies really became separate economic and therefore cultural units from the mother countries. It was the development of the ordinary occupations and economic independence that permitted the settlements to be mere colonies no longer. And, of course, the greater economic independence led to political independence.

The colonies themselves evolved from their situation as economic and social appendages of the metropolis and reached a state of development whereby they could be said to be wholly independent units, no longer relying upon the Metropolis for their economic cultural life. Partially this happened because they reached greater economies of scale, as noted earlier, but probably also because of their social maturity and because of the senility of the metropolis of Europe.

Just above we avoided the question of why these people traveled overseas to live very much the way they would have lived in Europe. It seems fairly obvious that for most of them the attraction was something available overseas that was not available to them at home--land! Land ownership meant high prestige and full citizenship in the Metropolis and was unavailable to the bulk of the populace. Because we live in a post-agricultural society, we cannot appreciate how attractive was the opportunity of land ownership to our forebears; even though this still has a vestigial survival in our country in the taste for the owned home as being much preferred to the rented home. It may be useful to speculate on what might substitute for land ownership in attracting ordinary people to build in-space or trans-space colonies. What will people value that would draw them away from the home planet? Obviously, money--but money also motivated our ancestors, and it seems that money can only be counted on to draw people into distant places on the mining-camp model--to make the quick buck and then return home. Something else, it seems, must be provided in order to get them to stay on a permanent basis. What was it that land provided to our ancestors? It seems that it offered three advantages--full citizenship, prestige, and

* Even without the tax advantages. In Canada, almost the same tendencies appear, even though there are no tax advantages to home ownership over renting.

independence. Under all modern systems, and it is difficult to think of it changing, citizenship is something which comes automatically by virtue of one's birth. In modern societies no possession or award provides the equivalent of the prestige which land offered in the early modern age, so we must leave that aside, although it may be possible that social conditions will change enough so that a special alternative could appear.

We must look to the last attribute of land as a possible motivating driver--independence. Perhaps people can gain a sense of individual liberty in a trans-space environment that is unavailable back in the homeland. This brings us back to the personality type discussed earlier--the sort of person who is not entirely happy with the restrictions of civilization. We return to the free-booter and the test pilot. It is probable that space colonies, however well regulated for survival, will not have the enormous complex web of regulations and restrictions that is found on Earth and, for that reason, may be more productive, despite whatever environmental or material drawbacks space settlements may have.

B. The Steppe Frontier

We thought to develop here the Steppe frontier of Europe in the same manner as the sea frontier, but found that the possible analogies to space were so thin that the analytical apparatus did not justify the effort necessary to spin out the ideas. However, one point does come from the abortive analysis: that the Steppe--that is, the Eurasian Steppe ranging from the Ukraine to the Pacific--which was a barrier only because it was occupied by nomad horsemen who could not be dislodged until rapid-fire firearms became available to the adjoining states, was not ever itself fully developed, any more than the use of the sea was. The improved plows of the nineteenth century permitted the cultivation of the Steppe, but only under colonial conditions. This is seen in the territory of what is the Soviet Union, but more familiarly in the American steppe--the Great Plains--or the Australian steppe--the Outback--where people live in an unusual manner: The Dakota farmer or the Australian sheepherder is prosperous and thoroughly integrated into the world's political, economic and social system, particularly through modern communications and air transit, but cannot be said to live a civilized life in the traditional sense. However, the life of the people in these isolated farms and stations offers a model for life in an unprepossessing and harsh environment--families isolated, exploiting the economic viability of very large spaces, and in communication with each other and with the larger world by means of high-tech transportation (aircraft) and communications (short-wave radio). This could be a model for the life of dwellers in space or in trans-space colonies. The steppe-dweller analogy suggests a stable or declining population after settlement, the relocation of young people, and retirement of the old to the comforts and conviviality of the Metropolis.

To summarize the examination of the frontiers of Europe in the early modern age as an analogy for and perhaps a metaphor for space exploration suggests certain possibilities, which could coincide with reasonable conjectures about space travel and colonization.

A general point remains to be made--the Metropolitan promoters of ocean transit saw it as a means to achieve their objectives according to their values, and the success did not change their minds. Insofar as the rulers and the aware elements of West Europe cared about the Great Frontier, it was in terms of state power, conquest, wealth, and luxuries.

But the motives of the actual ocean crossers diverged from those of the Metropolitans, perhaps merely because they were a tiny, mostly self-selected, minority culled from the population of the Metropolis--risk-takers, fast-buck artists, trouble-makers and criminals, and idealists/cranks--all who shared the willingness to abandon the familiarity and security of the metropolis for Something Else.

III. COLONIZATION--TERRESTRIAL AND EXTRATERRESTRIAL

This section considers the potential for space colonization by examining the history--that is, the scientific record--of colonization on the Earth.* Long a cliché of science fiction is the concept of extraterrestrial colonies in space. Usually for dramatic purposes the authors have presumed an environment rather like that of the Earth, with human-tolerable temperatures and a breathable atmosphere. Of course these conditions can be found everywhere, or almost everywhere on the Earth, yet the pattern of settlement here has been, to say the least, uneven, and these terrestrial variations may cast some light on the potential for space colonization.

Let us distinguish between "in-space" and "trans-space" settlements. The meaning of the first is evident; the second means settlements across space on another planetary body. Space is a medium through which people can travel, but they can also, at least in concept, reside more or less permanently there. It is by traveling across media that mankind has settled this Earth, so let us examine that experience first.

A. Trans-medium Settlements

At present, the prevailing scientific belief is that something resembling humanity as we understand it originated in Africa. This theory is subject to change without notice upon the discovery of a new skull somewhere else. The original "range" or limit of settlement of man was probably fairly limited, as is that of most animals. Early man needed gatherable foodstuffs, water, means of protection from predatory animals, and warmth--all of which were presumably available on the African savannah.

Humanity's range was made near-global by three fundamental inventions--clothing, fire, and weapons--which permitted domination over predators and penetration of colder climes. Of course, the Eskimoes colonized the Arctic with this technology. However, while the possible range was widened to near-world extent, the next important inventions narrowed the preferred range. Husbandry made human life more desirable in places where domestic animals flourished, and agriculture required conditions of sun, soil, and water which concentrated settlements.

* General statements are founded on wide reading macro-history. For the writing of this paper, reference was made to F. Braudel, The Mediterranean and the Mediterranean World in the Age of Philip II (New York, 1972); J. Hawkes, Prehistory and the Beginning of Civilization (New York, 1963); E. Huntington, Mainsprings of Civilization (New York, 1959); A.J. Toynbee, A Study in History (London, 1934-1961); F.J. Turner, The Frontier in American History (New York, 1920); W.P. Webb, The Great Frontier (Austin, Tex., 1952). A fine summary volume (although in my view flawed by excessive technological determinism) is W.H. O'Neil, The Rise of the West (Chicago, 1963).

The dawn of recorded history finds people living nearly everywhere around the world--intensely settled in a dozen "civilizations" in river valleys near the Equator, these surrounded by grazing "barbarian" cultures, and farther away, mixed primitive agricultural, hunting, and gathering societies. In the hottest and coldest climes were the least advanced social systems based almost purely on hunting and gathering.

Within all of these levels of development was constant migration and colonization, mostly moving by foot to seek newer and/or better sites for settlement according to the technological standards of the societies. On the whole, people seldom appear to be interested in adapting themselves to new environments--although obviously, the ancestors of the Esquimaux and the desert nomads did so. However, the converse is true--people modified the environment to suit them; indeed, it has been claimed that civilization was stimulated by the need to organize irrigation for agriculture; the extension of agriculture usually required the clearing of forests or the modification of grasslands; conversely, predatory grazing nomads, such as the Mongols, would deliberately destroy agriculture to provide a preferred ecology for their horses and cattle.

What we call the industrial revolution had fundamental effects on the pattern of settlement on Earth. The initial leading-edge was the exploitation of coal and iron. People moved toward the coal and iron and to the places where they could economically be processed. In almost all cases, this movement was toward the North, toward colder climes than were optimum for an agricultural system. So the centers of civilization, and of power, were in northwest Europe and in the heartland of North America, and shortly in northern China and Japan.

The output of the industrial revolution, of course, provided the means to live in these previously marginal places. And today, technology has developed to the point where people can live not only sufficiently but comfortably anywhere in the world.

Today, we are going through a transition toward a society which has been labeled "post-industrial." One of its key attributes is a decoupling of the conditions of life from economic necessity. Advanced transportation and communications permit people to live far from the places of production of basic needs--food, water, and fuel.

But--and here is the key point--while people can live anywhere, they prefer to live in limited areas. Throughout the world, we are witnessing what many analysts call "the Sun Belt shift"--people are moving south toward the sun, not just in the U.S., but in Canada, Europe, the Soviet Union, and Japan. People want to be warm and comfortable. With air conditioning available, there is a growing preference for occasional excessive heat over occasional excessive cold.

Significant areas of the world are being slowly depopulated--especially those occupied in the early days of the industrial revolution--the

coal-and-iron districts, the trolley-car cities, the last thrust of the agricultural frontier in the Canadian Prairie and the Australian Outback. On the other hand, we must note the continued colonization of Siberia, promoted by enormous government subsidies, and the continued colonization of Alaska, driven mostly by a residue of the American frontier spirit, and also the rapid growth of the Rocky Mountain West of the U.S.

But to turn again to the negative, consider Antarctica. It is only in this century that men could reach its shores, much less settle there, yet no one has. The use of the term "negative" above is significant to the subject at hand, because all of the places under discussion are extraordinarily better suited for and attractive to human habitation than are any trans-space sites which will be reachable in the foreseeable future.

Why should anyone live on the Moon when they won't live in Duluth? The answer is obvious. We cannot expect them to live there for either of the two most important reasons for preferring location--that is, being born there, or liking to live there. We must hope for something in the trans-space site that justifies the trouble to travel, the confined environment, and the lack of the amenities of civilization. The search for "something" is eased by the recognition that we need not seek a universal benefit--the early attraction need only be to a few (a hundredth of a percent of a world population of six billion is 600,000--no social data are accurate to a hundredth of a percent--so even an ambitious number of colonizers is well within the margin of error of world population).

The first something is fame--but only the "point men" get that.

The second something is personal satisfaction, which can be continued so long as the achievement is rare, like climbing a difficult mountain.

The third something is curiosity--part of the motivation of the tourist and the scientist.

The fourth something is status--another part of the motivation for the tourist and the scientist, as well as for the resident of the "exclusive" suburb or "up-scale" resort.

Not a something, in our view, is merely getting-away-from-it-all. Those who want that can do it rather easier on Earth. At least there is plenty of air, however cold or rarified, in Antarctica or the Himalayas. And unless some extraordinary technological breakthrough occurs, the necessities of providing an artificial environment will certainly put living space at a premium and require a level of intimacy for higher than that of Earth.

A related not-a-something is the monastery/commune. Both of these are more easily achieved on Earth--although it is possible for example

to imagine a space religion that sees Mars as Mount Sinai, requiring the presence of a few of the devout.

Alas, the obvious something that can bring most people to trans-space colonies is the most vulgar of motives--short-term greed. The historical analogue tells us that people will go trans-space for money, lots of fast money, so that they can return to Earth to spend it. Of course, a few might stay on, but most would want to make their poke and go back, perhaps to come out again when their wallets get thin. This motive also applies to scientists--who are, like everyone, careerist.

So based on existing precedent the question of colonization boils down to who will pay the colonists and for what?

The obvious analogous Earth settlement is the mining camp where there exists gold, or iron, or oil, or whatever, which has sufficient value to justify the expense of bringing it out from the wilderness. Men must be hired to build the facilities to bring it out, and to operate them once in place. Perhaps it is needless to remark that we cannot be sure that anything exists trans-space that is worth that trouble--indeed, given what we now know (granted, not much), it is at best uncertain that the Moon or Mars or the asteroids or the moons of the outer planets have material or energy worth planting a colony to exploit--but, of course, that estimate may be changed radically by further exploration and new technologies.

A rather more promising Earth-model is the military base. This is settled by people whose participation is not entirely voluntary. Some have been conscripted and others have volunteered for the military services, but not to be based in some particularly god-forsaken post. Nonetheless, some of the military has long been planted in such unfortunate places--sailors go to Little America, airmen go to Thule, Soviet forces to Kamchatka.

Depending on the organization of the service, dependents can often be brought along. Military settlement is one of the oldest and successful means of colonization. It was central to the policy of the Roman Empire. East Prussia began this way. The "Fort this-or-that" names which litter a map of the U.S. show the importance of military settlements in colonizing North America.

We can reasonably ask why a military post should be established trans-space--but that is another question to be developed later. We can write here that a military colony seems, given what little we now know, the most promising sort of early trans-space settlement with the "mining camp" second.

Third would be the scientific facility--the observatory, or monitoring station, or exploration base. But a settlement of this type assumes that automatic equipment would be inadequate for one reason or another.

But there is another side to the colonization coin. The assumption so far has been that people go to something better. That has been true in most cases--but an alternative spur to colonization cannot be ignored: that people migrate to escape something worse. For example, the Central European scientists who came to the U.S. in the 1930s were not enamored with American culture. They were reacting to a sharp deterioration--to understate considerably--of living conditions in their former abodes.

The planting of Puritan colonies in America in the early 17th century was a colonization of the negative type. The English Puritans were under heavy pressure from the political and ecclesiastical authorities of the Stuart government. Two factions (which our histories label "the Pilgrims" and "the Puritans") gave up the struggle and determined to create proper churches trans-atlantic. They moved too soon, because their compatriots at home over-threw the Stuart regime--and many of the emigres returned to participate in the fight and to enjoy the victory.

Obviously, the Puritan migration was a boon to what became America; and equally obviously, although the Stuart government was relieved to be rid of those trouble-makers, the migration reflected a worsening political climate in England. To apply this analogy to trans-space colonization would require speculating on something adverse happening on Earth or at least on some part of Earth. Something adverse would almost certainly have to be on all earth, because a deterioration in some part could be answered by a migration to another part.

We can easily imagine a world-tyranny (indeed, space-based weapon systems might be a powerful asset to such a regime). And despite the use of political examples above, it should not be ignored that environmental deterioration has probably been the principal spur to negative migration--e.g., when the hunting failed, or the crops failed.

The obvious problem is how to conceive of a world society in grave political or environmental danger finding the resources to devote to a space colony or some sub-group needing those resources. If there is a plausible forecast of imminent world destruction--by a comet or a virulent, perhaps man-caused, plague--then it would be good policy to throw all available resources into an exodus of even a tiny group; to mix the Biblical metaphor, this is an Ark strategy. And, while conceivable, is not likely, nor a suitable scenario for planning purposes.

If we think about one or two centuries hence, and if we believe that space travel will become so cheap that it may be available to small nations or sub-groups within large nations, then the negative migration scenario is possible.

B. In-medium Settlements

Discussions of Earth colonization take for granted that settlements must be on terra firma and ignore the possibility that people can live

in the transportation medium itself. So speculations about living in-space lead us to examine the history of living in on-earth mediums:

In a water colony people live on a boat instead of on dry land. In human history there are numerous examples of water colonies. In the days of the sailing ships, when voyages took months or years, the sailors effectively were sea residents. In many cities on estuaries (and most cities had to be on estuaries because they required water for drinking, washing, and sewage) were colonies of people living on boats more or less permanently tied up--houseboats. This is particularly noticeable in china and can be viewed easily in Hong Kong. This type of water colony is a function of the crowdedness and desirability of the city and presupposes, for whatever reason, a housing shortage. For example, some people lived in the yacht basin in the East Potomac Park in Washington, D.C., immediately following the Second World War, and a few dozen live in marinas along Manhattan Island today.

However, these numbers are infinitesimal and are probably shrinking. The reasons for this are obvious--transportation speed and flexibility have improved remarkably. The modern motorized ship can make its passage in a few weeks and a sailor can be home regularly. However, the development of effective motorized land transportation has permitted the city to spread out on the land, thus eliminating the pressure for people to live on the water. This movement away from water colonies brings to mind a set of factors which are negative when considering the possibility of in-space colonies. Keep in mind that water colonies are much easier for people to inhabit than space colonies, yet they are failing. To be sure, the pluses and minuses are quite different--water colonies are subject to the continual presence of water which has corrosive effects on wood, metal, and just about everything else. Overall the corrosive effects of space environment are likely to be much milder, but perhaps somewhat worse in terms of exposure to intense sunlight and penetrating radiation. The water colonies have the drawback of being dangerous in that people, especially children, always run the risk of drowning, but this is even more pronounced in a space colony where the entire environment outside of the protected area is certain to be fatal. The water colony has the drawback of limited food supplies--food either must be carried from shore or one can rely upon fish and seaweed. It remains to be seen what local food sources will become available in space, but the first approximation is that over the near term there will be none at all.

A closer analogy to a space colony is the air colony. Since the invention of the balloon, it has been possible for human beings to live in the air. Inhabitants of balloon colonies would have many

* Although some people live on ships today. This writer has boarded a molasses tanker which shuttled between Vera Cruz and Albany, New York. On it lived a few complete families; the tanker was a floating village.

advantages that would not accrue to land inhabitants--they would have a marvelous view, they could move their homes easily, and they would be away from it all. The obvious method of living in the air would be in a tethered balloon and it is theoretically possible, with long-standing technology, to conceive of extraordinarily large balloons and colonies of balloons. Just as the water colonist could catch fish, the air colonist could gather birds and, with suitable netting, perhaps some vegetable matter as well. But no single person, to our knowledge, has ever chosen to live in the air. And the air colonist has one great advantage over the space colonist in that whatever else he may lack, he does not lack air to breathe.

The closest Earth-bound equivalent to in-space living is undersea living. Indeed, many of the parallels are quite close. Because of buoyancy, the undersea dweller lives, in some respects, as if he were in a near-zero gravity condition. At moderate depths, he requires a "space suit, and he must be provided with an air/oxygen supply to survive. As has been discussed in the imaginative works of Jacques Cousteau and his associates, people could live underwater. Air/oxygen could be derived from water or from sea-bottom materials without excessive difficulty. Ample food, both animal and vegetable, is available from fish and plants. The economic justification for undersea colonies is easy to contrive--military and resource exploitation. Furthermore, many people are intensely and personally interested in underwater activity--via skin-diving and "professional" suited diving for commercial purposes. A handful of enthusiasts are steadily increasing the periods which people stay underwater--just as times in space increase--yet both activities are of a testing and record-breaking nature. No one shows any signs of wanting to permanently live underwater. And to repeat the theme, living underwater is now much easier than living in space.

In summary, considering only the historical record and contemporary trends, space colonization--either in-space or trans-space--would not appear to have much attraction for very large numbers of people. Space colonization is caught in a paradox--a world society rich enough to afford large-scale space travel is rich enough to provide extraordinary comfort and freedom-of-choice on Earth. The most promising possibilities of relatively long-term dwelling are the mining camp and the military base.

Nevertheless, this perspective may be time-bound--changing technology coupled with changing social values may soon force major revisions.